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# ACTIVATED SLUDGE TREATMENT OF CHROME TANNERY WASTES

A. C. Lawrence

U. S. Department of the Interior
Washington, D. C.

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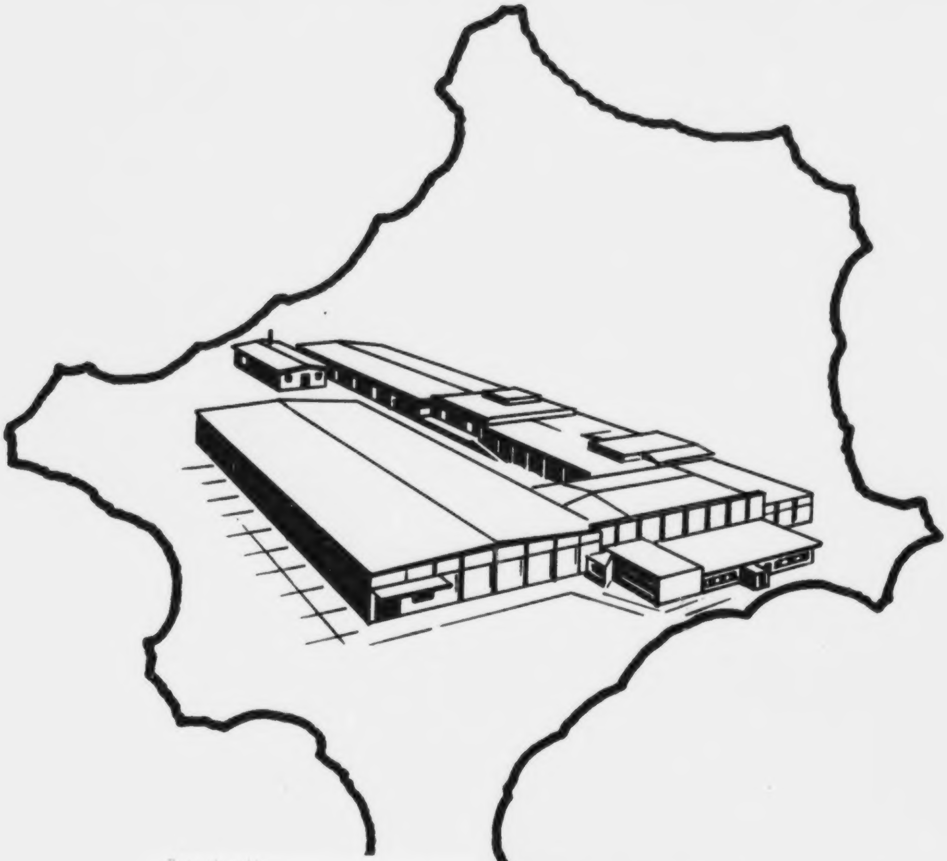

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# ACTIVATED SLUDGE TREATMENT OF CHROME TANNERY WASTES

## A PILOT STUDY OF TREATING COMBINED CHROME TANNERY WASTES AND DOMESTIC SEWAGE

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
DEPARTMENT OF THE INTERIOR

by

A.C. LAWRENCE LEATHER COMPANY
SOUTH PARIS, MAINE
GRANT NO. WPRD 133-01-68
PROGRAM NO. 12120
SEPTEMBER, 1969

## FWPCA Review Notice

This report has been reviewed by the Federal Water Pollution Control Administration and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Federal Water Pollution Control Administration.

# ABSTRACT

The A.C. Lawrence Leather Company tannery at South Paris, Maine is a chrome side upper leather tannery. About 220 people are employed at the tannery and about 2,500 hides are processed each day. The water use at the tannery is about 1.0 mgd. Each day the waste discharged from the tannery contains about 8,500 lbs of 5-day, 20°C BOD, 70,000 lbs of total solids, of which about 17,000 lbs are suspended and 53,000 lbs are dissolved. The pH of the wastewater varies from 5.0 to 12.0. The daily waste discharge also contains about 8,000 lbs of calcium, as $CaCO_3$, 300 lbs of sulfides, and 1,800 lbs of chromium.

A waste treatment process was developed and tested, in pilot plant scale, for the treatment of the tannery wastes in combination with municipal sewage. The process consisted of the following steps in the order employed; equalizing and mixing of the alkaline and acid wastes; primary sedimentation; carbonation followed by upflow sedimentation; addition of screened municipal sewage; activated sludge treatment and secondary sedimentation of the mixed wastes; and chlorination. The sludges resulting from the treatment of the wastes and sewage were dewatered by centrifuge and were found to be suitable for burial. Design factors for the various steps of the process were developed and are presented in the attached report. Studies were made of the fundamental systems and reactions which form the bases for the processes employed in the pilot plant.

The results of the pilot plant investigation indicate that by use of the methods recommended, mixtures of chrome tannery wastes and municipal sewage can be treated successfully. It may be anticipated that by the employment of the methods recommended, that mixtures of tannery wastes and municipal sewage can be treated to remove more than 90 percent of the BOD and suspended solids together with about 65 percent of the total solids. Furthermore, the treatment will remove or convert 99 to 100 percent of the sulfides, remove about 97 percent of the chromium and about 65 percent of the calcium. Chlorination of the effluent will reduce the coliform bacteria concentration to less than 100 per 100 ml.

The processes recommended are conventional sewage treatment unit processes, with the exception of carbonation and solids contact sedimentation. Modification of conventional equipment will be necessary to accommodate the special characteristics of tannery wastes. Fine screening will be needed to remove hair. Calcium carbonate incrustation of equipment, especially screens and carbonation equipment, will have to be considered. Extra strength sludge collection and pumping equipment will be needed since the sludges are large in quantity and are denser than sewage sludges.

This report was submitted in fulfillment of Grant No. WPRD-133-01-68 between the Federal Water Pollution Control Administration and the A.C. Lawrence Leather Company.

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# CONCLUSIONS

## General

The purpose of the pilot plant investigation was to determine the feasibility of treating the wastes from the A.C. Lawrence Leather Company's tannery at South Paris, Maine by the activated sludge process or a modification thereof. If the process was found to be technically feasible further investigation was to determine the loading factors leading to the design of the most economical treatment plant and method of operation required to meet the stream classification standards established by the Maine Water and Air Environmental Improvement Commission for the Little Androscoggin River, the receiving stream.

The unit processes investigated were:

1. Primary sedimentation
2. pH adjustment
   a. With $CO_2$
   b. With acid wastes
3. Activated sludge treatment
4. Sludge thickening

The investigation was divided into three phases. The objectives to be accomplished in each phase are described as follows:

### Phase 1

a. Determine the optimum conditions for the operation of the carbonation-primary sedimentation stage of the proposed wastewater treatment system.

b. Determine the removal efficiency for calcium, chromium, sulfide, BOD and suspended solids by pH adjustment, carbonation, and sedimentation.

c. Investigate the use of poly-electrolytes and other coagulant aids as means of increasing the efficiency of the carbonation-sedimentation process.

d. Build up an operating activated sludge system, using sanitary sewage from Norway, Maine, sewerage system.

### Phase 2

The objective of the Phase 2 operation was to demonstrate the ability of the proposed waste treatment system to remove pollution materials from the waste on a continuous basis and to determine the efficiency of the treatment. Determinations of the operating characteristics, such as feed to mixed liquor suspended solids ratios; excess sludge volumes; supplemental nutrient requirements; and effluent characteristics were made. An evaluation of the operating efficiency of the activated sludge unit as related to the operational efficiency of the carbonation-sedimentation unit were made.

## Phase 3

The objectives of Phase 3 were (a) to study the operating limits of the proposed system, (b) to determine the ultimate fate of the pollutional materials, and (c) to study sludge disposal by centrifuge dewatering and burial.

The pilot plant investigation was carried out in accordance with the purpose and objectives previously stated. The treatment methods are fully described in the main body of the report. The following unit processes, listed in order of application, were found to be essential to satisfactory treatment of the wastes.

1. Equalization
2. Primary sedimentation
3. Carbonation and sedimentation
4. Addition of municipal sewage
5. Activated sludge treatment
6. Sludge dewatering by centrifuge
7. Effluent chlorination

## RECOMMENDATIONS

On the basis of the pilot plant testing program, it is recommended that the wastes from the A.C. Lawrence Leather Company tannery at South Paris, be treated by the processes described below. These processes will be applicable to the treatment of wastewaters from the tanneries employing tanning methods similar to those described in this report.

### Equalization Basin

Wide fluctuations in the rate of discharge and the quality of the wastes discharged by a tannery render the treatment of the waste on a continuous, as received basis, unsatisfactory. One of the first steps in the treatment process should be an equalization of the wastes discharges relative to both flow and quality. Fig. 1 is a plot of the outflow concentrations of calcium from an equalization basin having detention times of 4 and 8 hours as compared with no equalization. From Fig. 1, it may be seen that the maximum fluctuation in the calcium concentration from an equalizing basin, having approximately 4 hours detention time, will be from about about 400 mg/l to 1700 mg/l. From an 8-hour retention time in the equalization basin, the maximum variation in the effluent calcium concentration would be from about 700 mg/l to 1500 mg/l. On the basis of this study, it is recommended that the equalization basin have a capacity of approximately 4 hours retention time, equivalent to a volume of 210,000 gallons for a design flow from the tannery of 1.25 mgd. It is estimated that the maximum concentration of the various constituents in the effluent from the equalization tank will be:

| | |
|---|---|
| Calcium | 1,700 mg/l |
| Sulfide | 190 |
| Total Solids | 19,500 |
| Suspended Solids | 4,320 |
| Alkalinity | 1,240 |
| Chromium | 460 |
| 5-day, 20°C BOD | 2,100 |

Special designs may permit the incorporation of the equalizing function in combination with carbonation, primary sedimentation and other processes. The functions which may be incorporated in a single basin is a decision which will have to be made during final design when a selection is made of the specific equipment to be used. Suggested designs are shown later but these designs should be investigated in more detail by the final designer in order to develop a unified system.

The operating cycles of the tannery are such that for periods of time up to 10 hours, the discharge of the tannery is predominantly acidic. In order to minimize the size of the equalization basin needed to prevent the pH of the mixed wastewaters from falling below 9.5 it is more economical to provide a separate storage basin for the acid waste and to add them to the equalization basin at a variable rate such that the maximum

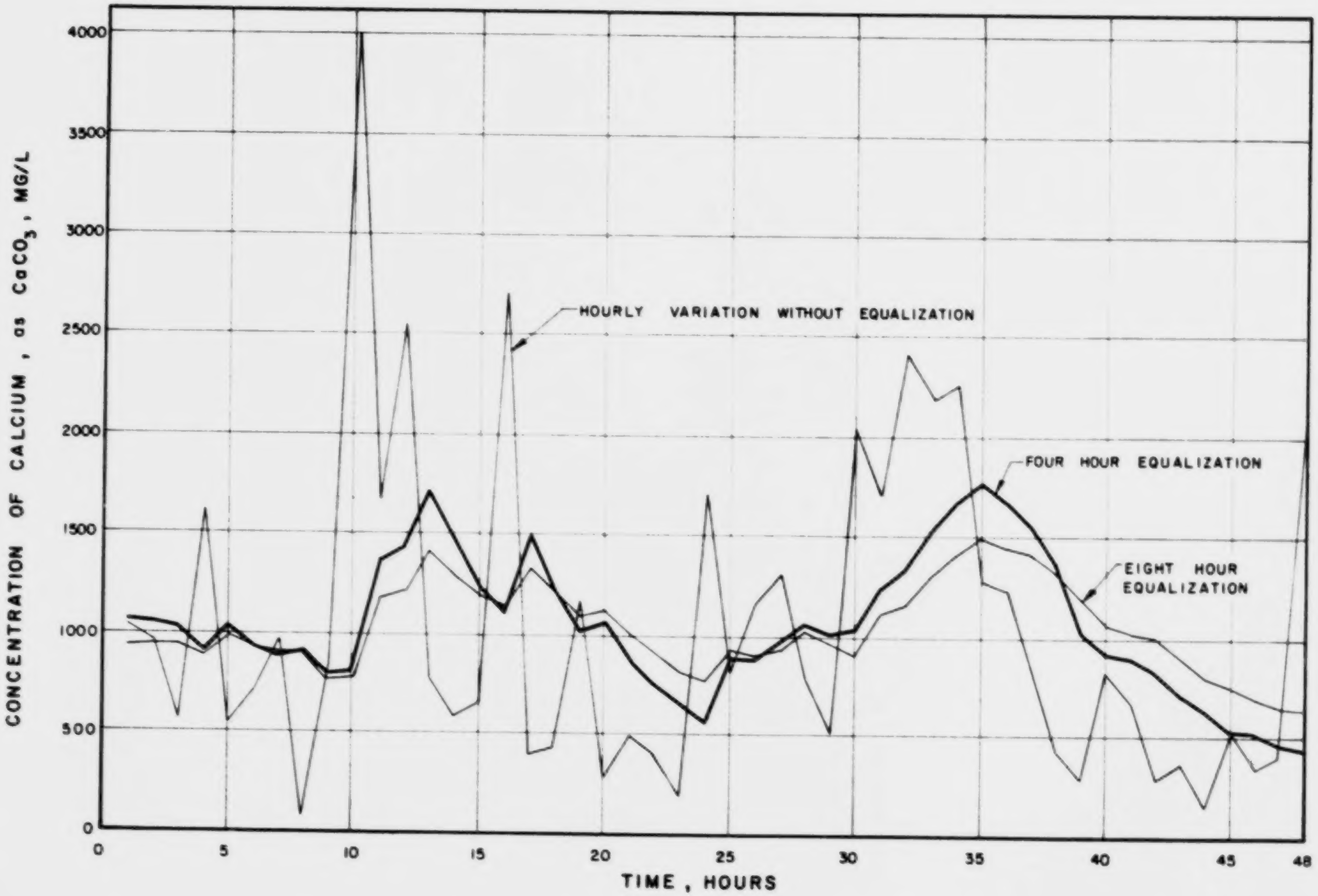


FIG. I EFFECT OF EQUALIZATION ON WASTEWATER QUALITY

rate of addition of acid waste will coincide with the maximum inflow of alkaline wastes. For this purpose, it is estimated that the size of the acid wastes holding tank should be about 100,000 gallons. Mixing of the wastes during equalization is considered to be essential. Mixing is particularly important when acid wastes are being added. No local areas of low pH should be permitted to develop within the equalization basin.

## Primary Sedimentation

In the pilot plant, primary sedimentation was found to be an essential feature of the treatment process. In the pilot plant, the primary sedimentation basin served two principal purposes. The first purpose was to equalize the fluctuations in influent quality so that minute to minute changes were ironed out. The second purpose was to remove the bulk of the settleable solids to prevent overloading the sedimentation section of the carbonation-upflow sedimentation basin which followed. These purposes are sucessfully accomplished. Similar functions are needed in a full-scale plant.

It is suggested that the functions of equalization and primary sedimentation may be carried out in the same basin but in different compartments. Fig. 2 is a sketch of one possible type of basin. Alternative designs are being investigated.

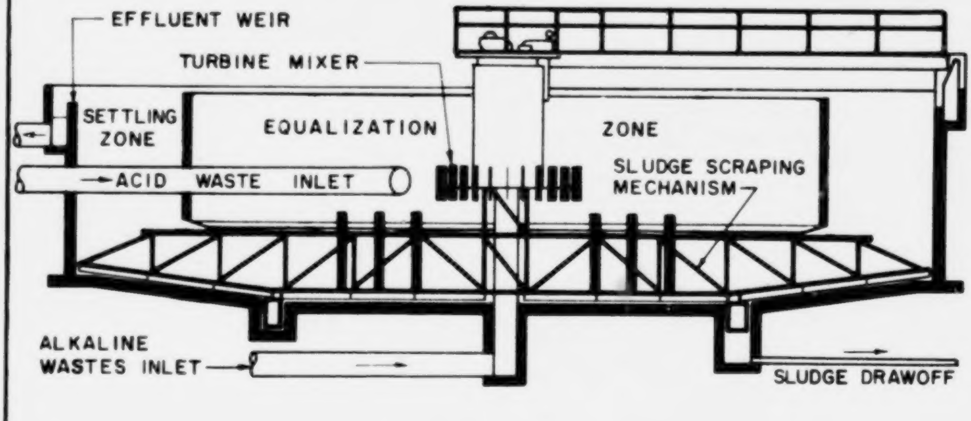
The sedimentation section of the basin should be designed with an overflow rate of about 700 gpd per ft.$^2$ Design on this basis will result in detention times of about 2 hours.

Special design consideration should be given to the removal of sludge from the sedimentation basins in the primary systems.

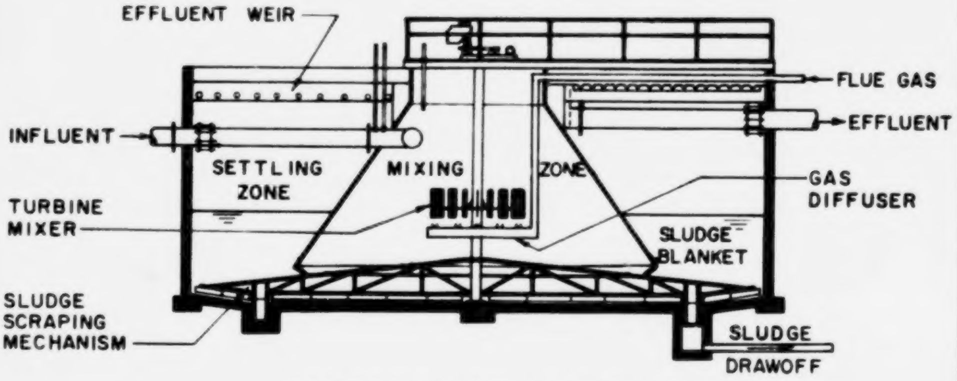
The sludge may have a concentration in excess of 8 percent solids. The solids will be heavy and sticky and in many respects resemble very wet clay. Sludge removal mechanisms should be of extra strength design. Sludge draw-off piping would be equipped with water flushing connections which should be used to flush out the sludge draw-off lines after each use. If these draw-off lines are left full of sludge, the sludge is of such a nature that it may set up and clog the pipes preventing any further draw-off of sludge until the pipes are cleaned.

## Carbonation

The pilot plant tests show that the rate of absorption of carbon dioxide from the flue gas is very rapid. It is estimated, therefore, that a 20 minute contact period in a basin which was supplied with flue gas will provide an ample opportunity for full absorption of carbon dioxide by the tannery waste. Carbonation should be preceded by equalization because changes in the rate of flow and the quality of the various discharges from the tannery is so rapid that adequate carbonation is not possible on an as received basis. Carbonation might well be preceeded by primary


EFFLUENT WEIR
TURBINE MIXER
SETTLING ZONE
EQUALIZATION
ZONE
ACID WASTE INLET
SLUDGE SCRAPING MECHANISM
ALKALINE WASTES INLET
SLUDGE DRAWOFF

EQUALIZATION AND PRIMARY SEDIMENTATION BASIN


EFFLUENT WEIR
FLUE GAS
INFLUENT
EFFLUENT
SETTLING ZONE
MIXING
ZONE
GAS DIFFUSER
TURBINE MIXER
SLUDGE BLANKET
SLUDGE SCRAPING MECHANISM
SLUDGE DRAWOFF

CARBONATION UPFLOW SEDIMENTATION BASIN

FIG. 2 -SUGGESTED TREATMENT PLANT EQUIPMENT

sedimentation to remove undissolved lime which interferes with proper carbonation. Carbonation should be followed by sedimentation in order to remove the calcium carbonate which is precipitated by the flue gas. Inasmuch as carbonation will require only a few minutes retention time, this process might very well be carried out in a channel located between an equalization basin and sedimentation basin.

On the basis of the wastewater survey, it is estimated that a capacity for adding about 1,800 lbs of carbon dioxide per day should be provided. If it is assumed that the flue gas contains 11 percent carbon dioxide and the efficiency of using the carbon dioxide in the flue gas is 50 percent, the volume of flue gas required will be about 2,600,000 cu ft per day or 1,700 cu ft per minute. On the same basis, it may be computed that it will be necessary to burn about 1,150 lbs of oil per day in order to generate the required quantity of flue gas.

## Aeration Basin Design

In the pilot plant, the aeration basin functioned in a manner normal to the activated sludge process. The only unusual reaction of the aeration basin was the formation of large quantities of a very stable foam. The foam was not a continuous problem but occurred from time to time. In the pilot plant the foam was controlled by the use of sprays and on occasion by anti-foaming agents.

It is recommended that the installation of the activated sludge process on a full-scale basis include foam control sprays and a chemical feed system for adding anti-foam agents to the spray system. In addition, surface aeration devices are recommended, because less foaming would be expected to occur than with the use of gas dispersion devices located beneath the liquid surface.

The aeration capacity to be provided should be sufficient to introduce about 10,000 lbs of oxygen per 24-hours into the waste. It is estimated that this will require aerators having a total power input of about 165 horsepower. The volume of the aeration basins should be about 1,000 cu ft for every 60 lbs of BOD treated. On this basis, the aeration basins would have a volume of 165,000 cu ft or about 1,250,000 gallons. Basins having a capacity of about 1,250,000 gallons would provide a 12-hour detention period for a waste and municipal sewage flow of about 2.5 mgd. It should be noted that this design provides for 1.25 mgd of tannery effluents and an equal amount of sanitary sewage from the Town of Paris.

## Secondary Sedimentation

The activated sludge generated by the pilot plant was very light and difficult to settle. Based, however, upon the results of the operation of the secondary sedimentation basin in the pilot plant it is recommended that in the full-scale plant the secondary sedimentation basin be designed for the overflow rate of not more than 500 gpd per sq ft per day. Pumping capacity equal to the influent flow to the treatment plant, i.e., about 1,800 gpm should be provided to return the sludge which settles in the bottom of the secondary sedimentation basin back to the aeration basin. This entire capacity may seldom be used but should be available if needed.

Excess sludge from the secondary sedimentation basin should be returned to the primary sedimentation basin and resettled with the primary sludge. The reason for this recommendation is that the secondary sludge was very difficult to dewater alone. However, mixing the secondary sludge with the primary sludge resulted in a mixture which dewatered readily.

## Sludge Dewatering

Although the sludge dewatered readily on sludge drying beds and there was no odor from the drying sludge, however for the following reasons it is recommended that sludge drying not be used at the proposed treatment plant in South Paris:

1. A large volume of sludge will be generated by the treatment processes (about 38,000 gallons per day). Large quantities of sludge will accumulate in a short period of time if not continuously removed.
2. If unfavorable drying conditions, such as occur in the winter, persist for any extended period of time the volume of sludge which would accumulate could become overwhelming.
3. Sludge drying beds require a great deal of hand labor in clearing and hauling away the sludge. In view of the cost of labor, manual handling of the sludge is not economically attractive.

It is recommended that the sludge be dewatered by the means of a solid bowl centrifuge. Such a centrifuge will produce a cake containing about 20 to 30 percent solids and will be sufficiently dry to truck to a final disposal site. Dewatering by centrifuge can be arranged in such a manner that the sludge is never handled manually. Mechanical dewatering of the sludge permits dewatering without regard to weather conditions. The land space required for mechanical dewatering of sludge permits a minimum use of land for wastewater treatment purposes.

It is recommended that the sludge be disposed of by the sanitary landfill method. It is estimated that about 2 acres of land per year will be needed if the sludge is placed in layers 6 ft deep.

## COST ESTIMATES

Cost estimates have been made and are based upon design criteria set forth in these recommendations with flow and effluent characteristics existing at the studied location. The total capital and operating cost of the full scale treatment of combined tannery and municipal effluent is estimated to be 1.6 cents per foot of leather based upon present costs.

# INTRODUCTION

The A.C. Lawrence Leather Company operates a tannery in Paris, Maine. The tannery is located immediately south of the built-up section of the Village of South Paris on the west bank of the Little Androscoggin River. The tannery processes salted cowhides to finished leather. In 1968 the tannery processed about 97,000 lbs (2,100 hides) per day. The management at the tannery estimates that the maximum capacity of the existing plant is about 144,000 lbs of hides per day. The tannery operates about 23 days per month and employs about 220 people, divided into three shifts.

The processes utilized at the tannery may be generally classified as beamhouse operations, tanning and dyeing operations, and finishing operations. These operations are described in detail later. The waste from these operations amounts to about 1 mgd (million gallons per day) which, after partial treatment by lagoons, is discharged to the Little Androscoggin River. The river is badly polluted as a result of these wastes, especially during periods of low stream flow.

A report of the results of an engineering investigation and pilot plant study of the treatment of the tannery waste carried out by Camp, Dresser & McKee, Consulting Engineers, was submitted to the A.C. Lawrence Leather Company in June, 1967. At that time, it was recommended that additional experimental work should be carried out to more fully explore the treatment processes recommended. A FWPCA (Federal Water Pollution Control Administration) research grant was awarded the A.C. Lawrence Leather Company to carry out a more extensive pilot plant program.

## DESCRIPTION OF THE TANNING PROCESS

### General

Tanning is the process whereby the normally putrescible proteins in animal skin are preserved. A brief outline of the histology of skin will give an insight into the sources of organic load in the wastewater in the tanning operation which derive from the skin itself.

The skin as it arrives at the tannery consists of two layers, the flesh and the derma. Strictly speaking the flesh is not a part of the skin proper. Varying amounts of flesh may be attached to the skin, depending on the processing employed at the meat packing plant, and the skill of the flayer who removes the skin from the carcass.

The flesh layer must be removed by the tannery in the early stages of processing. This flesh contains muscle tissue, fat cells, blood vessels and adipose tissue, some of which finds its way into the wastewaters from the tannery.

The derma layer is the portion of the hide or skin which ultimately becomes leather. The derma is a complex material, consisting of two broad subdivisions; the epidermis and the corium.

The epidermis is the top layer of the skin, and contains the hair, hair follicles, and oil glands which surround the hair roots. The surface of the ipidermis is covered with a very thin layer of non leather-making protein. Running through the epidermis is a connecting network of collagen, the leather-making protein. During the early stages of leather processing all of these undesirable materials are removed from the skin. They are keratin, elastin, mucoids, albumens, and other proteins and alkaloids; and a significant amount of fat.

The corium is the major part of the skin and is composed primarily of the protein collagen. This collagen for the most part is an interwoven network of fibers and fiber bundles. It is the objective of the tanner to cleanse the skin of as much of the non-leather making debris as possible, and to process or "tan" the remaining collagen fibers to render them strong, flexible and non-putrescible.

As can be seen from the brief description above, the chemistry of skin is essentially the chemistry of protein. During the early stages of the leather manufacturing process many of these proteins are hydrolyzed or otherwise broken down and removed from the skin. Much of the colloidal and dissolved protein breakdown products appear in the wastewater. Very little is known about the susceptibility of these waste products to bacterial attack in the biochemical oxygen demand test for pollution studies. It may be that of efficient biochemical oxidation of these proteins requires an acclimatized culture containing specialized enzymes.

## The Tanning Process

In order to understand the problems involved in treating the effluent from the South Paris, Maine, tannery it is necessary to include at this point a description of the tanning process.

This tannery is a chrome side upper leather tannery. That is to say, cowhides and steerhides are converted into a leather by the process known in the trade as chrome tanning, a distinguished from other methods such as alum or vegetable tanning. The following is a general description of the various steps in the process. Fig 3 is a flow diagram of the tanning operations indicating the sources of the various types of wastes.

## The Beamhouse

The hides are received from thymeat packer or hide broker in bundles and have been salted or brined to preserve them. They may also have been "prefleshed" at the packing plant. The freshly flayed hides, if they are to be prefleshed are processed through a machine which removes the greater portion of the flesh from the skin. Following this step the hides are treated with sodium chloride. The common method of doing this today is to immerse the skins in a circulating saturated brine, which also serves to cleanse the skin of much of the manure, dirt, blood, etc., which is associated with it. Treatment with sodium chloride dehydrates the protein and renders it less susceptible to spoilage. The hids are then packed in bundles for shipment to the tannery.

At the tannery the bundles are opened up and the hides are cut down the backbone into two halves or "sides". As a consequence of the preservation method the next step at the tannery consists of removing much of the salt from skins and restoring moisture to render them flexible and receptive to processing chemicals. This process is referred to as soaking. The sides from the hide storage area are placed in large pits equipped with paddle wheels which serve to circulate the contents. The pits contain water to which a small amount of a wetting agent may be added. From time to time, the sides are agitated by operating the paddle. Midway through the first soak small quantities of sodium sulfide and lime are added. After about 14 hours the paddle pits are drained and refilled with fresh water, and the stock is washed with running water for a short time.

Fleshing follows soaking. Fleshing consists of passing the sides through a machine with rotating helical blades which remove the excess flesh from the sides. Water runs on the blades to keep them free of debris. The solid fleshings are collected in a box equipped with drain holes, the liquid waste passing to the sewer.

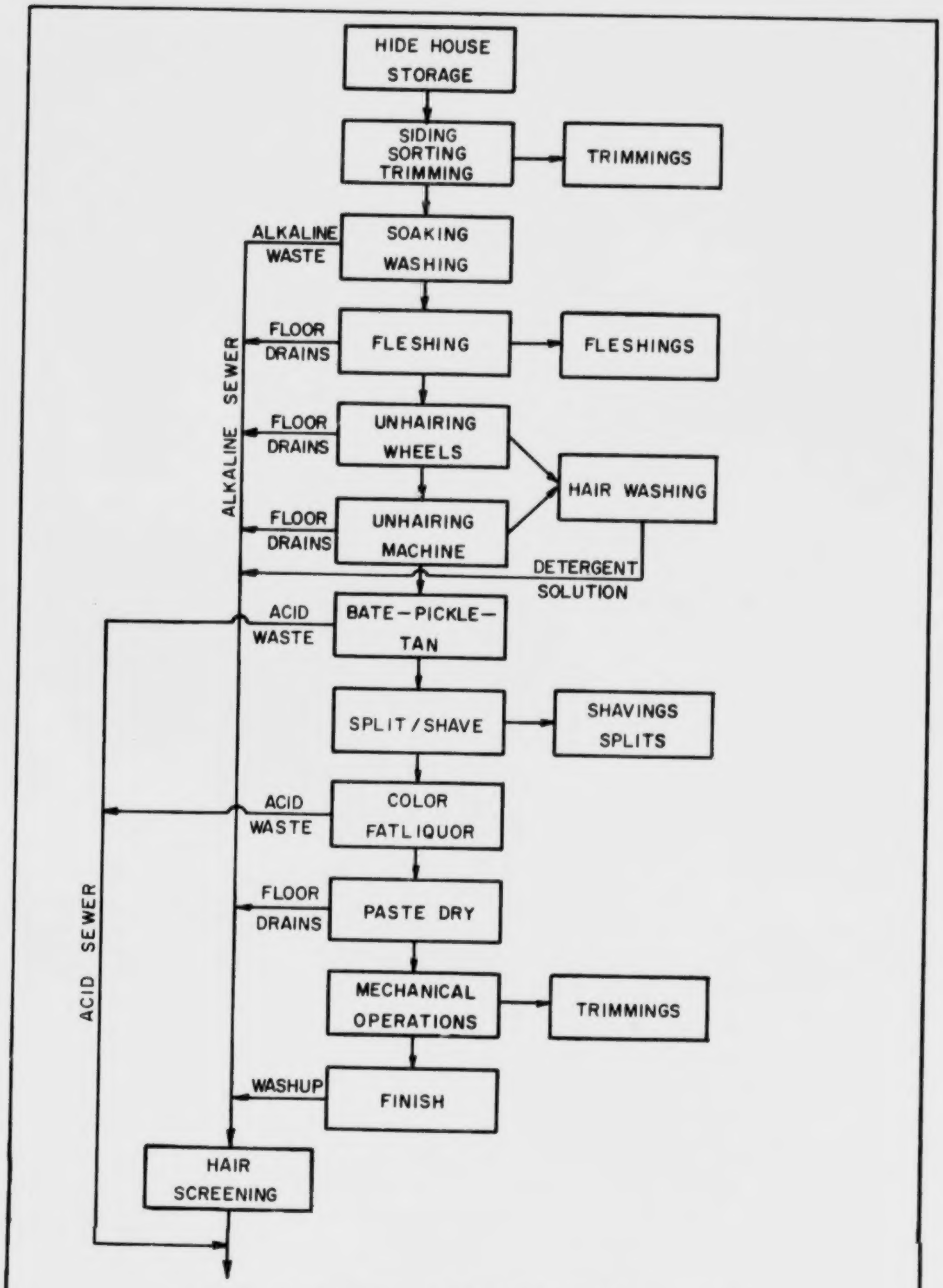

HIDE HOUSE STORAGE
SIDING SORTING TRIMMING
TRIMMINGS
ALKALINE WASTE
SOAKING WASHING
FLOOR DRAINS
FLESHING
FLESHINGS
ALKALINE SEWER
FLOOR DRAINS
UNHAIRING WHEELS
HAIR WASHING
FLOOR DRAINS
UNHAIRING MACHINE
DETERGENT SOLUTION
ACID WASTE
BATE-PICKLE-TAN
SPLIT/SHAVE
SHAVINGS SPLITS
ACID WASTE
COLOR FATLIQUOR
ACID SEWER
FLOOR DRAINS
PASTE DRY
MECHANICAL OPERATIONS
TRIMMINGS
WASHUP
FINISH
HAIR SCREENING

FIG. 3 TANNERY PROCESS FLOW SHEET

The next operation is unhairing. This operation consists of loosening the hair by treating the sides with a chemical solution described below, followed by mechanical removal of the hair in a machine similar to a fleshing machine. The sides are placed in a "drum" or "wheel", a large cylindrical container which is rotated at a slow speed. Water, sodium sulfhydrate, lime, and small amounts of other chemicals are added to the drum. After a suitable length of time in this solution, the hair has been loosened from the skin. The liquid is drained and may be passed to a holding tank to be refortified and reused. The sides are washed with running water, dumped, and forwarded to the unhairing machines. The hair removed in the machines is retrieved from the water and goes to a hair reclamation area where it is washed, dried and baled. All washings, containing small particles of protein solids, grease, sulfide and other chemicals go into the effluent stream.

Liming follows the unhairing step. In this step the sides are immersed in a lime suspension in a paddle and occasionally agitated to insure a uniformity of treatment. Sodium sulfide in a small amount may be added to the lime pit also. This operation swells the skin and opens up the finely interwoven collagen fiber bundles. Non-leather making protein and other undesirable debris is loosened from the skin so that it may be removed. Following a suitable treatment time in this solution the sides are pulled from the paddle and are passed to a scudding machine. "Scudding" consists of putting the sides through a machine which scrapes the grain surface with a dull blade. This serves to remove remaining hair roots, epidermal keratinous tissue and other surface debris. This debris passes to the effluent stream.

The above described operations constitute what is known as the beamhouse operation. The following part of the leather-making operation is known as tanning and coloring and is described below.

## Tanning and Coloring

As a result of the several processes in the beamhouse, the sides are now in a highly swollen alkaline state. Before the collagen will accept and react with the tanning materials, it must be made acid and the swelling must be removed.

The first step in this process is bating and deliming. In this process the sides are first placed in a drum and washed thoroughly. This is followed by treatment with a proteolytic enzyme at a pH of about 9.0. This pH is attained by the addition of ammonium sulfate which acts as a deliming salt. A small amount of detergent may also be added. The enzyme acts on the noncollagenous proteins in the grain surface of the leather and contributes to the final soft pleasant grain character achieved in the finished leather. Following a suitable length of time in this solution, the stock is washed in running water to stop the bating action and remove the solubized lime as calcium sulfate.

Pickling follows and consists of lowering the pH of the stock to about 2.0 with sulfuric acid. This is done in a sodium chloride solution, which acts to repress the swelling and keep the stock in a firm, "fallen" state.

When the pickling has proceeded to the desired point, the tanning material is run into the rotating drum. This consists of a complex salt of chromium resulting from the reduction of sodium bichromate with sulfuric acid and an organic compound such as sucrose. This tanning solution is allowed to penetrate the skin following which the pH is slowly raised by the addition of sodium bicarbonate to a pH of about 3.5. This causes the chromium salt to combine chemically with the collagen, thus producing leather. The excess solution is drained to waste and the leather is washed in running water.

Following tanning the leather is subjected to several mechanical operations as follows. First, the leather is wrung to extract as much moisture as possible. The leather then goes to a splitting machine, which is essentially a horizontal band knife. This machine splits the leather into the grain, or top layer and the split, or bottom layer. This bottom layer referred to in the trade as a "blue split" or "chrome split" is not processed further in the South Paris tannery, but is sold to custom finishers who process it into shoe linings, insoles, slipper soles, etc. The grain proceeds to a shaving machine, where the back is further leveled and smoothed by shaving off any unevenness which may be present. The chrome shavings thus produced are retrieved, baled and sold as a byproduct. A certain amount of the fine shavings adhere to the moist, fibrous back of the leather and are carried into the next operation which is coloring and oiling, and eventually find their way into the effluent.

Following shaving the sides are put into the coloring and oiling or "fatliquoring" wheels for further processing. It is here that the leather may be retanned with chromium salts, synthetic tanning materials (syntans), and the fibrous structure partially filled with clay or other fillers. These operations are all performed in a water medium and washing usually follows each processing step. Here also dye solutions are applied depending on the shade desired in the finished leather. The dyes are customarily fixed or made fast with formic acid. Finally oils are introduced into the drum, usually as oil-in-water emulsions. As these emulsions are broken at the leather surface the oil is worked into the leather. The oils commonly used are cod, sperm and other animal and fish oils, usually sulfated sufficiently to cause them to be self-emulsifiable. In some cases additional emulsifiers and stabilizers are added.

From the above description of the coloring and oiling procedure it is apparent that a great variety of both organic and inorganic pollutants find their way into the tannery effluent from this source. The next processes at the tannery are completed with the coloring and oiling procedure.

A relatively non-polluted effluent is discharged from the pasting and oiling. Pastings is the method employed to dry the leather. The sides are affixed to smooth porcelainized steel plates which have previously been sprayed with a water dispersible paste. The plates with the leather adhered to them are passed into a heated drier where the moisture is driven out of the leather. After the leather has been stripped from the plates, they are passed through a washer which removes the old paste, sending it to the sewer. A fresh paste is then applied to the surface.

After drying, the leather is subjected to a variety of dry mechanical operations and ultimately arrives in the finishing department where the final processing steps are performed.

## Finishing

In finishing side leather for shoe uppers it is necessary to apply a pigment finish to the surface of the leather to make the surface uniform in appearance and of the shade desired. "Pigment finish" is simply pigment, organic and inorganic, dispersed in a suitable emulsified resin binder. It may be modified with plasticizers, waxes, etc., to give the handling characteristics and surface feel desired. A small amount of waste, principally machine clean-up water is discharged in this operation.

With the exception of plant clean-up water and discharges from compressor cooling and boiler room and the above constitute the sources of waste from the tannery.

# EFFLUENT SURVEYS

## Previous Effluent Surveys

Prior to the present pilot plant study, four effluent surveys had been conducted at the tannery at South Paris. The results of the previous surveys were studied prior to undertaking the pilot plant investigation. The results of studies and surveys which were available are listed below:

1. Surface water sampling by the State of Maine Water Improvement Commission for 1956 and 1959.
2. Report entitled "Waste Flow Analysis, Plant and Unit Operation Studies," Hydroscience, Inc., Leonia, New Jersey, July, 1964.
3. Sewerage Tests - South Paris, July 9, July 27, August 2, 1965, Summary Report, dated October 22, 1965 to Mr. M.H. Battles from J.A. Bassett, Technical Department.
4. Report entitled "Pilot Plant Investigation of Wastewater Treatment at South Paris, Maine," Camp, Dresser & McKee, Boston, Massachusetts, June, 1967.

The results of the waste surveys previously made were individually averaged to obtain the best possible estimate of the waste discharges for the periods investigated in 1959, 1964, 1965 and 1966. These estimates are summarized in Table 1. The results in Table 1 show no particular trend. The results do indicate, however, that large quantities of waste materials are discharged from the tannery each day. The magnitude of these discharges is indicated best by the total solids and the BOD value. The total solids in the effluent amounted to about 40,000 lbs per day and the BOD ranged from 5,000 to 8,000 lbs per day according to the past surveys.

## Present Effluent Surveys

Since the last survey, in 1966, the tannery made substantial increases in the rate of production and some changes in the processes employed. Therefore, in connection with the pilot plant work, it was considered essential to carry out further waste surveys. Initially, two 24-hour surveys were made , one on December 14, 1967, and one on January 2, 1968. After studying the results of these 24-hour surveys, it was felt that the picture of the waste discharges presented by the results of the surveys was incomplete. This conclusion was based upon the manner in which the tannery operates. A batch of hides is started on one day and requires approximately two to three days to pass through the entire process. Such a manner of operation results in a two to three day cycle of changes in the effluent

## TABLE 1 SUMMARY OF PREVIOUS WASTEWATER SURVEYS AT A.C. LAWRENCE LEATHER COMPANY TANNERY, SOUTH PARIS, MAINE

| Date | 1959 | April 1964 | June - August 1965 |
|---|---|---|---|
| Source of survey | Maine Water Improvement Commission | Hydroscience | A. C. Lawrence Leather Co. |
| Flow, gpd | | 1,045,000 | 650,000 |
| pH | | | |
| Alkalinity, (as Ca $CO_3$), lbs/day | | | 2,488 |
| Total solids, lbs/day | | 40,625 | 34,905 |
| Total volatile solids, lbs/day | | | |
| Suspended solids, lbs/day | | 13,540 | 7,024 |
| Volatile suspended solids, lbs/day | | | |
| Settleable solids, gals/day | | | 782 |
| Calcium (As Ca $CO_3$), lbs/day | | | |
| Sulfides ( as S), lbs/day | | 1,550 | |
| Chromium (as Cr), lbs/day | | | |
| BOD, 5-day, 20°C., lbs/day | 5,100 | 6,790 | 5,000 |
| COD, lbs/day | | 31,165 | 16,284 |

characteristics. In order to overcome this deficiency in the December and January waste surveys, a third survey was carried out on April 9 and April 10, 1968. The April 9-10 survey was a 48-hour survey.

The December 14, 1967 and the January 2, 1968 surveys were conducted in the following manner. All the effluents from the tannery, both acid and alkaline, come together into a single open flume which conducts the flow to a series of waste retention lagoons. A section of the flume downstream from the junction of the acid and alkaline discharges was selected for the sampling point. At this location, a measuring weir box was installed. The weir box consisted of a channel about 15 ft long by 3 ft wide and about 2 ft deep. The inlet to the chamber was baffled in such a manner as to distribute the flow uniformly across the cross-section of the channel. At the end of the channel a sharp edge rectangular weir, having a crest width of 1 ft, was installed. The crest of the weir was approximately 1 ft above the bottom of the channel. The downstream slope of the channel was such that, even at the highest flows, the crest of the measuring weir was not submerged. A measuring gage was installed in the channel approximately 2 ft upstream from the weir. Head measurements were made in a stilling section. A weir calibration chart was drawn up and supplied to the men collecting the samples.

Starting at 8:00 a.m. on December 14, 1967, samples were collected every 20 minutes until 8:00 a.m. on December 15, 1967. The sample procedure was followed for the January 2, 1968 survey. The samples were taken from the weir overflow using a dipper and ladling into a pail. Immediately after collecting the sample, the depth of flow over the weir was measured and the flow computed. Immediate measurements were made of the temperature, pH, alkalinity and settleable solids from each sample. The contents of the pail were stirred vigorously and a sample was taken having a volume proportional to the flow. The sample was composited for further analysis. Composites representing each two hours of flow were made up in this manner. The composite samples were analyzed for BOD, total solids, total volatile solids, suspended solids, volatile suspended solids, and calcium. The results of these two surveys are summarized in Table 2 and Table 3 respectively.

The 48-hour survey conducted April 9 and 10, 1968 was somewhat more inclusive. During the April survey, samples were collected each 15 min and composited hourly on the basis of flow. pH and temperature were measured at the time of collection. Tests for alkalinity, acidity, calcium, sulfide, total solids, total volatile solids, suspended solids, volatile suspended solids, 5-day 20°C BOD, and settleable solids, were conducted on each hourly composite. Composites of flow for 2 hr periods were analyzed for chromium. The results of this 48-hour survey are presented in Table A-26 and summarized in Table 4. The results are also presented graphically in Figs. A-1 through A-6 in the appendix.

## TABLE 2 SUMMARY OF 24 HOUR SURVEY OF TOTAL WASTEWATER DISCHARGE DECEMBER 14 TO 15, 1967

| | |
|---|---|
| Flow (gpd) | 801,520 |
| pH Range | 6.1 - 11.7 |
| Alkalinity to pH 8.3 as $CaCO_3$ (lb/day) | 2,620 |
| 5 day 20°C BOD (lb/day) | 7,180 |
| Settleable Solids (gals/day) | 70,810 |
| Total Solids (lbs/day) | 47,150 |
| Total Volatile Solids (lbs/day) | 14,060 |
| Suspended Solids (lbs/day) | 11,260 |
| Volatile Suspended Solids (lbs/day) | 8,480 |
| Calcium as $CaCO_3$ (lbs/day) | 5,960 |

# TABLE 3 SUMMARY OF 24 HOUR SURVEY OF TOTAL WASTEWATER DISCHARGE JANUARY 2 to 3 1968

| | |
|---|---|
| Flow (gpd) | 805,920 |
| pH Range | 5.7 - 11.2 |
| Alkalinity to pH 8.3 as $CaCO_3$ (lbs/day) | 1,470 |
| 5 day 20°C BOD (lb/day) | 6,790 |
| Settleable Solids (gals/day) | 62,540 |
| Total Solids (lbs/day) | 44,830 |
| Total Volatile Solids (lbs/day) | 12,020 |
| Suspended Solids (lbs/day) | 11,350 |
| Volatile Suspended Solids (lbs/day) | 6,540 |
| Calcium as $CaCO_3$ (lbs/day) | 6,200 |

## TABLE 4 SUMMARY OF 48 HOUR SURVEY OF TOTAL WASTEWATER DISCHARGE APRIL 9 TO 11, 1968

|  | 4/9 4/10<br>8:00 am - 8:00 am | 4/10 4/11<br>8:00 am - 8:00 am | 4/9 - 4/11<br>AVG/DAY |
|---|---|---|---|
| Flow (gpd) | 911,000 | 958,000 | 934,000 |
| pH Range | 5.2 - 12.0 | 5.0 - 11.6 | 5.0 - 12.0 |
| Alkalinity to pH 8.3 as $CaCO_3$ (lbs/day) | 2,345 | 3,319 | 2,832 |
| BOD (lb/day) | 8,244 | 8,880 | 8,562 |
| Settleable Solids (gals/day) | 144,230 | 116,620 | 130,425 |
| Total Solids (lbs/day) | 75,600 | 64,280 | 69,940 |
| Total Volatile Solids (lbs/day) | 24,420 | 16,390 | 20,405 |
| Suspended Solids (lbs/day) | 19,350 | 14,830 | 17,090 |
| Volatile Suspended Solids (lbs/day) | 12,270 | 8,980 | 10,625 |
| Calcium as $CaCO_3$ (lbs/day) | 8,160 | 8,390 | 8,275 |
| Sulfides as S (lbs/day) | 309 | 519 | 414 |
| Chromium as Cr (lbs/day) | 1,870 | 1,802 | 1,836 |
| Hides into soak (lbs, hidehouse wt.) | 90,000[1] | 121,500 | 105,750 |
| Hides into lime (lbs, soaked, fleshed wt.) | 109,200[2] | 101,400[2] | 105,300 |
| Hides into tan (lbs, white wt.) | 142,800[2] | 117,600[2] | 130,200 |
| Hides out of tan (lbs, white wt.) | 134,400[2] | 142,800[2] | 138,600 |

[1] 1506 of the total 3,936 sides were trimmed and fleshed prior to weighing.

[2] 6750 lbs of green, salted, untrimmed hides or 6000 lbs of green, salted, trimmed and fleshed hides is equivalent to 7800 lb soaked and fleshed hides and is also equivalent to 8400 lb white weight of hides.

From Table 4 the summary of the 48-hour survey results, it may be seen that the flow was relatively uniform from day to day, being 911,000 gpd on April 9, and 958,000 gpd on April 10, with the average flow for the two days being 934,000 gpd. The alkalinity summarized in Table 4 is the net alkalinity for the periods indicated. To arrive at this figure, the total acidity was subtracted from the total alkalinity resulting in the net alkalinity for the day as shown in Table 4. For April 9, the net alkalinity was 3,345 lbs per day (as $CaCO_3$) and for April 10, the net alkalinity was 3,319 lbs per day, while the average for the 48-hour period was 2,832 lbs per day. The BOD also appears to be quite constant from day to day. For April 10, the BOD was 8,880 lbs. Based upon the approximate weight of 105,000 lbs of raw hides being processed per day, the BOD amounts to 8.16 lbs of BOD per pound of hide processed. The solids show a somewhat wide fluctuation from day to day. The average settleable solids for the 48-hour period amounts to 130,425 gpd. The average total solids amount to about 70,000 lbs per day with a total volatile solids content of about 20,400. The volatile solids content is, therefore, only 29 percent. The low percentage of volatile solids is a reflection of the high content of inorganic materials, which are predominately sodium chloride, calcium hydroxide, sodium sulfide, and the chromium compounds employed in the tannery or washed from the hides. The suspended solids amount to about 17,000 lbs per day, of which about 11,000 are volatile. The volatile solids content of the suspended portion of the solids amount to about 8,300 lbs per day. The sulfide content, expressed as sulfur, is about 400 lbs per day and the chromium content of the wastewaters, expressed as chromium is about 1,800 lbs per day. The weight of the chromium in the wastewaters is equivalent to about 1.3 to 1.4 lbs of chromium per 100 lbs of wet hides being tanned.

## Acid Waste Survey

In order to gain a deeper understanding of the wastes produced by the tanning and coloring processes, an acid wastes survey was conducted on March 5, 1968. This particular survey was made by sampling and measuring the input and output of a number of individual tanning and coloring wheels. Samples were collected from the liquid contents of each wheel just prior to discharge to the sewer. Samples were analyzed both separately and as composites. The results of the acid waste survey are summarized in Tables 5 and 6. The basis of the summary is the amount of wastes which would be discharged from 15 tanning wheels and 23 color wheels in a 24-hour period. At the time of the survey, 126,000 lbs of wet hide were being tanned and about the same amount of wet hides were being colored. It was found that 267,600 gallons of acid waste is produced each day. The acidity of this waste is equivalent to about 1,500 lbs of calcium carbonate each day.

The results found in the acid waste survey correspond quite closely to those found on the 48-hour sampling. The total chromium found in the acid wastes survey amounted to 1,610 lbs of chromium per day, which compares quite favorably with the total of 1,800 lbs per day found for the

## TABLE 5
## COMPOSITE OF TAN WHEEL EFFLUENT

| | Quantity Per Wheel | Quantity Per Day |
|---|---|---|
| Total Volume, gallons | 10,020 | 150,000 |
| pH | 7.2 | 7.2 |
| Acidity, as $CaCO_3$, to pH 4.5, lbs | 0 | 0 |
| to pH 8.3, lbs | 2.8 | 42. |
| BOD, 5-day 20°C, lbs | 140 | 2,100 |
| Total Solids, lbs | 636 | 9,550 |
| Total Volatile Solids, lbs | 134 | 2,000 |
| Suspended Solids, lbs | 104 | 1,560 |
| Volatile Suspended Solids, lbs | 42 | 630 |
| Settleable Solids, gallons | 3,000 | 45,000 |
| Chromium as Cr, lbs | 74 | 1,110 |
| Pounds of hides | 8,400 | 126,000 |

## TABLE 6

## COMPOSITES OF COLOR WHEELS EFFLUENT

| | Quantity per Wheel | | |
|---|---|---|---|
| | Tropical | Casco | Quantity Per Day |
| Total Volume, gallons | 5,160 | 5,090 | 117,000 |
| pH | 3.85 | 3.85 | 3.85 |
| Acidity, as $CaCO_3$ to pH 4.5, lbs | 0.7 | 0.6 | 14 |
| to pH 8.3, lbs | 3.5 | 5.1 | 100 |
| BOD, 5-day 20°C, lbs | 54 | 32 | 1,000 |
| Total Solids, lbs | 190 | 224 | 4,850 |
| Total Volatile Solids, lbs | 92 | 90 | 2,100 |
| Suspended Solids, lbs | 46 | 42 | 1,000 |
| Volatile Suspended Solids, lbs | 32 | 30 | 710 |
| Settleable Solids, gallons | 340 gals | 510 gals | 9,800 |
| Chromium as Cr, lbs | 19 | 24 | 500 |

48-hour survey. The total BOD in the acid wastes amounts to about 3,100 lbs per day or about 3/8th of the total BOD. The total solids in the acid wastes amount to about 15,400 lbs per day or about 21 percent of the solids in the total tannery effluent. Analysis of these results reveal that most of the minerals in the wastewater are derived from the salt and lime discharged from the beamhouse. On the other hand, the tanning and coloring processes use about 28 percent of the water used by the tannery.

## Discussion of Survey Results

One observation which was made during the course of the surveys and the pilot plant operation, which is not readily seen from the study of the survey results, is the effect of mixing the alkaline beamhouse wastes with the acid tan house wastes. Mixing of the two wastes results in a considerable increase in the suspended solids. When the mixture contains an excess of the alkaline wastes such that the pH of the mixture is above about 8.5 most of the chromium which is in solution in the acid wastes, is precipitated as chromium hydroxide. The resultant flocculant material tends to coagulate many colloidal particles which otherwise would not settle. The settleable solids are thereby greatly increased in the mixture over that found in the individual waste streams. The total amount of settleable solids which would be obtained by a uniform mixing of the acid and alkaline wastes is not reflected to the full extent in the 48-hour survey because many of the acid discharges took place when an excess of alkalinity was not present and therefore the precipitation of chromium hydroxide did not occur at such times. However, in the pilot plant operation, acid wastes were proportioned to the total flow in such a manner that excess alkalinity was always present and the maximum effect of the chromium hydroxide coagulation was obtained.

All analyses made during the survey, with the exception of the analysis for chromium, was done in accordance with the twelfth edition of "Standard Method for the Examination of Water and Wastewater." The analyses for chromium were performed at the central laboratory of the A.C. Lawrence Leather Company in Peabody, Massachusetts.

Two basic methods were used for the determination of chromium in a sample. If the sample was thought to have a high chromium concentration, such as the various sludges or the contents of a tanning wheel, the sample was analyzed according to the American Leather Chemists Official Method D-10, which consists of evaporating the sample to dryness and ashing in an oxidizing atmosphere. The ashed sample is then fused with a mixture of sodium carbonate, potassium carbonate, and boraz. The fusion is dissolved in hot, distilled water, excess potassium iodide added, and the iodine released is titrated with sodium thiosulphate. For samples thought to have a low concentration of chromium, such as treatment plant effluents, the sample is oxidized with potassium permanganate and diphneylcarbazide is added. The resulting color is measured spectrophotometrically at a wavelength of 540 $m\mu$.

# THE PILOT PLANT

## Purpose of the Pilot Plant

Tannery wastes have many characteristics which make the treatment of these wastes extremely difficult. The pH of the wastes fluctuate widely throughout the day, ranging from 3 to 12. The wastes have a high concentration of sulfide (up to more than 700 mg/l), chromium concentrations of more than 500 mg/l, fungicides which very in concentration and characteristics depending upon the particular procedures being used in the tannery, and detergents of various kinds. In general, past attempts to treat tannery wastes have been far from satisfactory.

The documentation of treatment methods which have not been successful is difficult, because failures are seldom published. Problems normally encountered include unsatisfactory treatment by primary sedimentation, clogging of trickling filters by precipitated calcium carbonate, blinding of vacuum filters dewatering sludge and odors resulting from waste lagooning.

Previous studies (1) of the tannery effluent at South Paris indicated that supplemental nutrients might be needed to achieve successful biological treatment of the wastes. It was felt that the addition of municipal sanitary sewage to the tannery would supply the necessary nutrients. Other literature supported this viewpoint (2),(3),(4). Furthermore, joint treatment of municipal sewage and tannery wastes offers a number of other advantages such as reduced overall costs and availability of state and federal aid in financing joint treatment works. Hence, one of the purposes of this investigation was to determine the implications of this method of treatment.

The industrial waste treatment literature contains many reports of methods for the treatment of tannery wastes (2),(3),(4),(5),(6). Most of the investigations reported in the literature are laboratory scale tests or small pilot plant tests under controlled conditions. Very few experimental results are available for full-scale waste treatment works. Most full-scale treatment of tannery wastes has consisted of primary sedimentation or disposal to some type of lagoon system. Treatment by primary sedimentation alone or by lagooning has usually resulted in the generation of obnoxious hydrogen sulphide odors and an effluent which was unsuitable for discharge to high quality receiving waters. Treatment methods based on small scale experimental investigations have not been generally adopted because of the narrow scope of these investigations, the high cost of the construction of the required treatment works and the uncertainty that the final results would meet with the designer's expectations. In view of the general lack of knowledge concerning the treatment of tannery wastes, it was considered essential to conduct pilot plant studies to determine the most feasible and economic method of treating the effluent from the tannery at South Paris.

The general type of treatment to be investigated by the pilot plant method at South Paris was determined by three considerations:

1. The degree of treatment required, because of the classification of the Little Androscoggin River, was very high, in excess of 90 percent removal of BOD and suspended solids.
2. The nature of the tannery wastes. Surveys indicated that the wastes were high in BOD. BOD at times exceeded 4500 mg/l. High cromium content and high sulfide content.
3. The need to develop the most economic system available.

The degree of treatment required was quite high. The only biological treatment which appeared to offer the required degree of treatment was the activated sludge process. Trickling filters were considered, however, the experience of clogging of trickling filters by calcium carbonate (7) lead to rejection of this method of treatment.

The pilot plant was, therefore, developed on the basis of utilizing the activated sludge process. Since the activated sludge process is a biological process, it was necessary to provide such pretreatment of the waste as might be required to reduce the concentration of biologically toxic materials to levels tolerable to the process.

The characteristic of the waste which appeared to be the most harmful to biological processes was the rapid and extreme fluctuation in the pH as it was discharged from the tannery. The tannery effluent survey indicated that the low pH acid wastes were discharged from the tanning and coloring process and the high pH wastes were discharged from the beamhouse process. It was obvious that the first step for reducing the fluctuations in pH should consist of a uniform mixing of the alkaline and acid wastes discharges. Chemical analysis and computations indicated however, that the quantity of acid wastes was insufficient to neutralize completely all of the alkaline wastes. It was therefore, necessary to effect a further reduction of pH before the mixed waste was acceptable for biological treatment. Carbon dioxide was selected as the most satisfactory agent for the necessary pH reduction. Carbon dioxide was selected because it will react with the excess lime which is present to form an insoluble precipitate of calcium carbonate, which may then be removed from the waste by sedimentation. Carbon dioxide is available at the tannery in large quantities in the flue gases from the power house stacks. Carbon dioxide is a safe material to handle and does not present the hazards involved with handling and storage of strong acids in liquid form.

Literature studies indicated that while chromium is toxic to some forms of biological life, in particular algae and green plants (8), the organisms which are active in the activated sludge process are tolerant of chromium in concentrations of less than 50 mg/l (9). Furthermore, a study of the chemistry of chromium indicated that a great deal of chromium will be removed from the waste during the pretreatment stage as chromium hydroxide, provided the pH of the waste is maintained above 8.5 to 9.0.

It should be noted that all of the chromium encountered in the wastewater at the tannery was in the tri-valent form.

The presence of high concentrations of sulfide in the waste created a serious problem. If the pH of the waste mixture is reduced below 8.5, the chemical equilibrium of the sulfide is such that hydrogen sulfide gas will be given off in amounts that will be intolerable both from the viewpoint of atmospheric odors and toxicity to personnel in the vicinity.

The tolerance of the activated sludge process for sulfide was not known. Our previous studies and those of others (10) indicated, however, that an acclimated activated sludge process will rapidly remove or alter the sulfide in waters containing the concentrations of sulfide comparable to those expected under average conditions in the South Paris tannery discharges. However, it was not known if the process would be adversely affected by high concentrations of sulfide in the form of surges which are discharged by the tannery.

A further purpose of the pilot plant investigation was to determine design factors for full-scale treatment works. It was necessary to determine such factors as the maximum rate of oxygen uptake by an activated sludge system treating the tannery waste; the rates at which the suspended solids will be removed by primary sedimentation and by secondary sedimentation; the value of polyelectrolytes for assisting sedimentation; the rate and degree of uptake by the waste of carbon dioxide in flue gas; the rates of formation and precipitation of calcium carbonate in the complex tannery effluent; the degree of BOD removal which can be achieved by the activated sludge process; the availability of nutrients for supporting the activated process; the volume and concentration of both primary and secondary sludge which will be produced; the dewatering characteristics of sludge; the chlorine demand of the treated effluent; and an economic evaluation of the process applied to a real situation. The pilot plant was designed to operate over a fairly wide range of flows in order to determine the optimum operating point for each of the unit processes involved.

## Pilot Plant Design

A process flow sheet for the pilot plant is presented in Fig. 4. The treatment units in the order of utilization in the process are an alkaline waste storage tank, an acid waste storage tank, an alkaline waste feed pump, an acid waste feed pump, a mixing box, a primary sedimentation basin, a carbonation basin feed pump, a combination upflow-carbonation-sedimentation basin, a flue gas pump, a sanitary sewage storage basin, an activated sludge aeration basin, a foam trap, a secondary sedimentation basin, and a sludge dewatering centrifuge (not shown on Fig. 4).

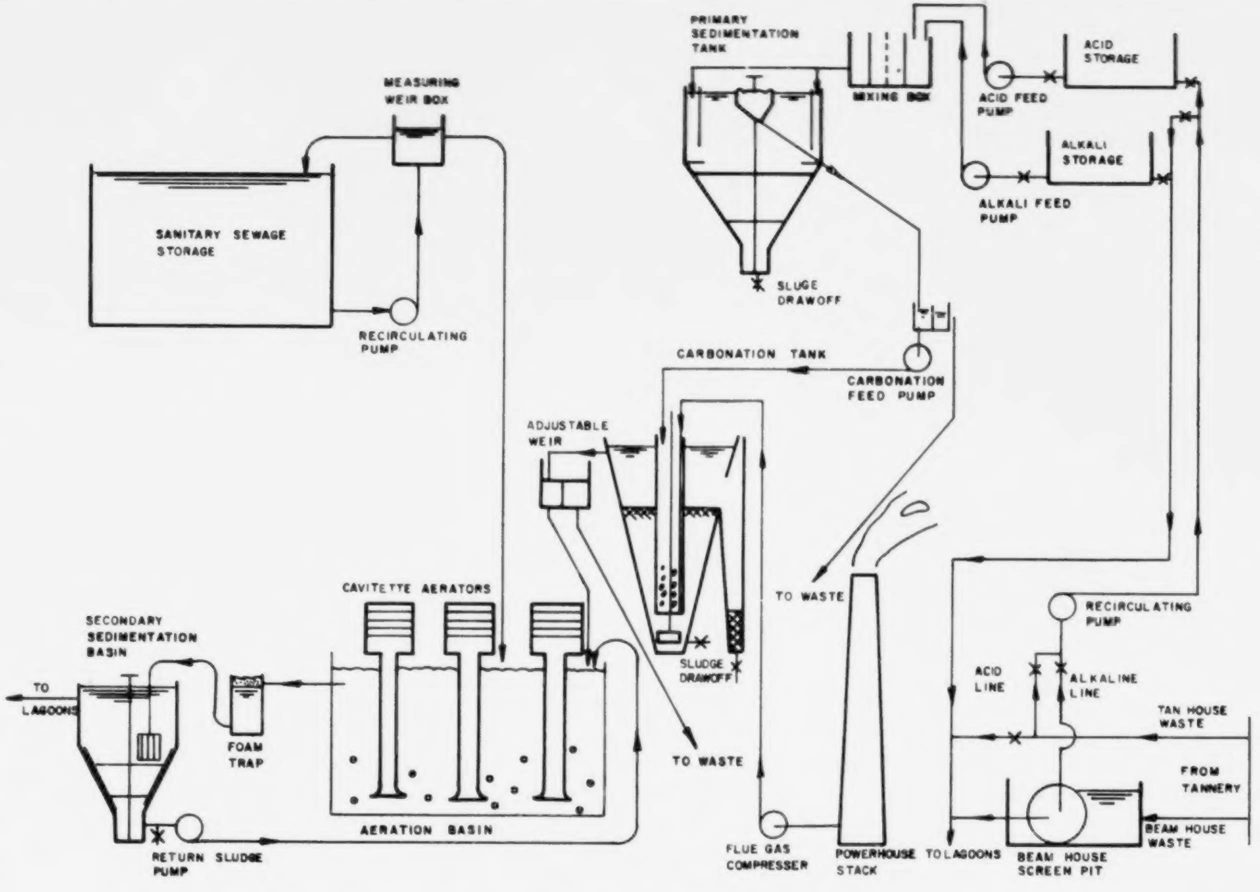

PRIMARY SEDIMENTATION TANK
MIXING BOX
ACID FEED PUMP
ACID STORAGE
ALKALI STORAGE
ALKALI FEED PUMP
MEASURING WEIR BOX
SANITARY SEWAGE STORAGE
RECIRCULATING PUMP
SLUGE DRAWOFF
CARBONATION TANK
CARBONATION FEED PUMP
ADJUSTABLE WEIR
TO WASTE
CAVITETTE AERATORS
SECONDARY SEDIMENTATION BASIN
TO LAGOONS
FOAM TRAP
SLUDGE DRAWOFF
TO WASTE
AERATION BASIN
RETURN SLUDGE PUMP
FLUE GAS COMPRESSER
POWERHOUSE STACK
TO LAGOONS
RECIRCULATING PUMP
ACID LINE
ALKALINE LINE
TAN HOUSE WASTE
FROM TANNERY
BEAM HOUSE WASTE
BEAM HOUSE SCREEN PIT

FIG. 4 FLOW SHEET FOR PILOT PLANT

The waste treatment pilot plant was normally operated in the following manner:

The alkaline waste flow from the tannery was continuous and constituted the largest single volume of waste discharged from the tannery. The alkaline waste was discharged from the tannery immediately following fine screening through a drum screen. Screening was for the purpose of hair and gross solids removal. The acid waste was discharged intermittently through a separate outlet. The following method was used to obtain the portions of acid and alkaline wastes used in the pilot plant.

The alkaline waste was pumped from a discharge sump, following screening, into a piping system which circulated through the pilot plant and back into the alkaline waste discharge. The circulating pumping system operated continuously except when the tannery was shut-down on weekends. At the pilot plant, a small progressing cavity positive displacement metering pump pumped at a fixed rate from the recirculating line to the mixing box. Thus, the flow of alkaline waste to the pilot plant mixing box fluctuated in quality in a manner representative of the tannery alkaline discharge; however, the rate of flow to the pilot plant was constant. Since the flow in the acid discharge line was intermittent, it was necessary to pump from the acid discharge line at such times as flow was available. When there was flow in the acid discharge line, the acid wastes were pumped to an acid storage tank in the pilot plant. In the acid storage tank, the acid waste was gently mixed to keep solids in suspension. Furthermore the acid waste was adjusted to a constant strength, equivalent to the average strength of the acid waste discharged throughout a 24-hour period. The acid waste was then pumped from the acid storage tank to the mixing box by a positive displacement metering pump. The acid feed pump was adjusted hourly on the basis of the concentration of alkalinity in the alkaline discharge. Adjustments were made in an attempt to maintain a nearly constant alkalinity in the pilot plant influent. However, it was not possible to maintain a constant alkalinity and wide fluctuations still occurred. However, these fluctuations were minimized as much as possible. Great care was taken, however, to insure that the pH of the mixed waste did not fall below 9.0 and thus generate toxic $H_2S$ gases.

During the initial stages of the pilot plant studies, no primary sedimentation was employed. However, the amounts of sludge which were encountered when the beamhouse waste was mixed with the acid tanning wastes were so excessive as to overload the settling section of the unit and render operation of succeeding units unsatisfactory. Hence, after about three months of initial operation, a primary sedimentation basin was installed. Following the mixing of the acid and alkaline wastes the flow entered the primary sedimentation basin. The primary sedimentation basin was a modified rim feed circular basin with the effluent take-off at a central weir. The bottom of the primary sedimentation basin was conical and equipped with scrapers to insure the movement of the sludge to a central draw-off valve. The primary sedimentation basin was 4 ft in diameter and had a side water depth of 3 ft and a center water depth of 6 ft 8-in. The net surface area was 11.5 sq ft and the capacity was 355 gallons.

The effluent from the primary sedimentation basin was pumped to the combination upflow sedimentation-carbonation basin. Fig. 5 is a section through the carbonation-upflow-sedimentation basin. The carbonation-sedimentation basin consisted of two compartments. The inner compartment was a square column about 6.5 ft long with an interior cross section about 10-in on each side. The column was mounted vertically at the center of the upflow compartment. The upflow compartment was constructed in the shape of an inverted pyramid: the top was 4 ft on each side tapering to 1 ft on each side at the bottom. The central column was supported about 1 ft from the bottom. The liquid depth of this basin was about 7.5 ft. The total volume of the unit was 350 gallons including about 50 gallons in the central compartment. Mounted in the central compartment near the bottom was a diffuser for flue gas.

The diffuser consisted of a short length of rubber tubing with one end closed tightly and the other end attached to the gas supply pipe. Small slits were cut in the rubber tubing to disperse the gas. The rubber tubing diffuser was developed after considerable trouble had been experienced from build-up of calcium carbonate on the orifices of more conventional type diffusing systems. The initial diffuser consisted of an 8-in diameter ring formed from 1/2-in copper tubing. The ring contained 10 1/16-in holes. These holes soon clogged with precipitated calcium carbonate. The holes were enlarged to 3/16-in diameter but they still clogged. Clogging occurred because calcium carbonate deposites built up as small hollow cones around each hole. As the height of the cones increased the openings became smaller and the pressure needed to exhaust the flue gas increased. Eventually it became necessary to remove the diffuser ring and clean the holes. The problem was increased by the intrusion of waste into the diffuser when the flow of flue gas was shut off. The rubber tubing served two purposes. If calcium carbonate tended to build-up around the slits the rubber would stretch and flex and break off the accumulation. When the gas was shut-off, the slits would close and prevent the waste from entering the gas lines.

The effluent from the sedimentation section of the carbonation basin was taken off near the surface through two horizontal parallel pipes having 1/4-in diameter holes spaced three inches on centers. Sludge removal from the upflow basin was accomplished in a sludge concentration hopper located on one side of the tank. The sludge overflow weir, giving access to the hopper, was located at a distance of 5 ft from the bottom of the unit. Sludge was also removed from the bottom of the flow through section, especially before the primary basin was installed. At times, before the installation of the primary sedimentation basin, more sludge was found in the flow through compartment than in the sludge hopper. In order to prevent the flow from channeling through the sludge blanket, a mixing blade was installed near the bottom of the hopper. The mixing blade was 9-in long by 3-in wide and was mounted on a vertical shaft which was rotated through a speed reducer. The speed of rotation was about 100 rpm.

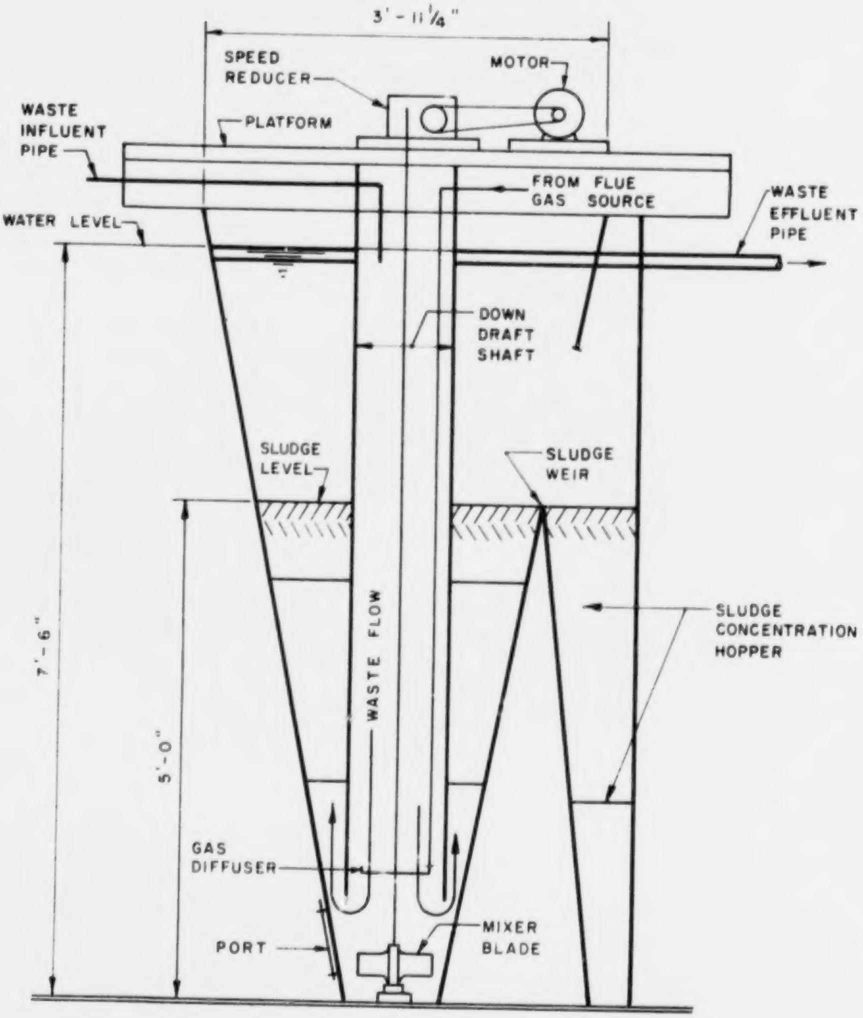

3'-11 1/4"
SPEED REDUCER
MOTOR
WASTE INFLUENT PIPE
PLATFORM
FROM FLUE GAS SOURCE
WATER LEVEL
WASTE EFFLUENT PIPE
DOWN DRAFT SHAFT
SLUDGE LEVEL
SLUDGE WEIR
7'-6"
5'-0"
WASTE FLOW
SLUDGE CONCENTRATION HOPPER
GAS DIFFUSER
PORT
MIXER BLADE

FIG. 5 SECTION THROUGH CARBONATION SEDIMENTATION UNIT

The net surface area at the water surface was 14.1 sq ft. The cross section area of the sedimentation-carbonation unit at the level of the sludge weir was 8.25 sq ft net.

The carbonation-sedimentation unit was operated in the following manner. The influent flow was introduced near the top of the central column. The flow was downward through the central column and upward through the expanding section of the sedimentation portion. Carbon dioxide or flue gas was introduced through the gas diffusion piping at a point near the bottom of the central column. Therefore, the gas flow was upward and the liquid flow was downward providing good contact between the gas bubbles and the alkaline wastes. The flow was then under the bottom edge of the central column and upward through a sludge blanket approximately 4 ft deep. The sludge blanket provided ample contact between previously precipitated calcium carbonate sludge and the supersaturated calcium carbonate solution passing through it. As the level of the sludge blanket increased above the sludge weir, the excess sludge settled into the sludge concentration hopper. The clarified effluent was removed near the surface of the liquid in the basin.

From the carbonation basin, the flow was directly to the activated sludge unit. The activated sludge unit consisted of a cylindrical steel tank with a flat bottom. The tank was about 8 ft in diameter and had a water depth of 4 ft. The operating volume of the tank was 1500 gallons. Aeration and mixing were furnished by three mechanical aeration "cavitette" units. These machines introduced air into the activated sludge by drawing air through a hollow shaft by the cavitation created at the tips of the impeller which was located about 39-in below the water surface. The impeller served to draw in air, break-up and mix the bubbles of air into the fluid and to stir the aeration basin contents. Each cavitette unit was powered by a 1 HP electric motor.

During some phases of the operation of the aeration unit, considerable amounts of foam occurred in the aeration basin. When the foam was permitted to flow into the secondary sedimentation basin, the rising foam created convection currents and tended to float some fine solids which reduced the efficiency of the basin. In order to overcome this difficulty a foam trap was installed between the aeration basin and the secondary sedimentation basin. The foam trap consisted of a 30 gallon steel drum having an inlet near the surface and an outlet at the bottom. This device was successful in intercepting and retaining the foam from the aeration basin. From time to time, the foam was removed from the surface of the foam trap and manually returned to the activated sludge aeration unit.

The secondary sedimentation basin was a cylindrical steel tank with a conical bottom. The diameter of the tank was 4 ft and the straight side water depth was 4 ft. The conical bottom had a slope of 1 on 1. The basin was equipped with mechanical scrapers which prevented sludge from adhering to the sloping bottom. Settled sludge was continuously removed from the bottom of the secondary sedimentation basin and pumped back to the aeration basin. The clarified effluent from the secondary sedimentation basin was removed at the surface of the basin by a small overflow weir.

Sludge from the primary sedimentation basin, the combined carbonation-upflow-sedimentation basin, and the excess sludge from the secondary sedimentation basin were removed manually as required. The volume of all sludge removed from the sedimentation basins was measured and a sample collected for analysis.

During the pilot plant operation, tests were made relative to the dewatering of the various sludges, both singularly and in combination. Dewatering was investigated using a standard 6-in solid bowl continuous flow centrifuge. Dewatering tests were also conducted using sand drying beds. The sand drying beds were constructed by perforating the bottoms of four 30 gallon steel drums and constructing the drying beds in these drums. The drying beds consisted of a 3-in layer of 1/4-in pea stone in the bottom of each 30 gallon drum. The pea stone supported a 4-in layer of common concrete type of sand which formed the surface of the drying bed. A 12-in layer of each type of sludge was placed on the surface of the sand and its drainage and drying characteristics observed.

Table 7 presents a summary of the design factors for the various units of the pilot plant. Each unit was designed to operate at a flow rate slightly less than the preceeding unit and the excess flow was discharged to waste between units. It should be understood, however, that the pilot plant was operated at rates of flow both above and below the design rate. However, the same principle applied in that each unit was operated at a flow rate slightly less than the preceeding unit. The purpose of this step-down design was to insure flexibility of operation. Each unit could be operated at rates of flow independent of the flow rate of the preceeding units. The efficiency of the primary basin could thus be measured at various flow rates without affecting the operation of the secondary system.

One of the purposes of the pilot plant was to demonstrate the treatment of a mixture of tannery effluent and sanitary sewage. Since the Town of Paris has no municipal sewerage system, sewage was obtained from the outfall of the Norway, Maine, municipal sewage system. Sanitary sewage was obtained daily except Sunday, and was transported to the South Paris pilot plant by tank truck. The sanitary sewage was stored in an elevated, 3,000 gallon storage tank from whence it was pumped and metered directly into the activated sludge unit. The sanitary sewage had been comminuted and was screened through a screen box having 1/4-in openings. The contents of the storage tank were maintained in suspension by a circulation pump.

### Log of Pilot Plant Operation

The following log of the operation of the pilot plant is furnished so that a reader who wishes to study the complete analytical data of the pilot plant results as presented in Tables 1A through 25A may know the operating status of the plant on any particular day.

## TABLE 7. A.C. LAWRENCE LEATHER COMPANY WASTEWATER PILOT PLANT

### Design Factors and Operating Range

| Characteristic | Design Factor | Operating Range Tested |
|---|---|---|
| **PRIMARY SEDIMENTATION BASIN** | | |
| Circular, conical bottom, rim inlet, center weir overflow. | | |
| Diameter, ft | 4.0 | |
| Side water depth, ft | 3.0 | |
| Center depth, ft | 6.66 | |
| Net surface area, $ft^2$ | 11.5 | |
| Volume, gals | 355.0 | |
| Flow, gpm | 5.0 | 5.25-20.0 |
| Surface overflow rate, gpd/$ft^2$ | 625.0 | 660-2,500 |
| Detention time, hrs | 1.2 | 1.15-0.3 |
| **CARBONATION-UPFLOW SEDIMENTATION BASIN** | | |
| Square in plan, upside down pyramid, square center column for carbonation, side sludge hopper. | | |
| **CARBONATION COLUMN** | | |
| Side, ft | 0.92 | |
| Depth, ft | 6.5 | |
| Volume, gals | 41.0 | |
| Flow, gpm | 5.0 | 4.0-15.0 |
| Detention time, min | 8.0 | 10.0- 2.7 |
| **UPFLOW SEDIMENTATION** | | |
| Side length, ft | 3.9 | |
| Liquid depth, ft | 7.9 | |
| Net surface area, $ft^2$ | 14.1 | |
| Volume, gals | 306.0 | |
| Sludge blanket depth, ft | 5.0 | |
| Net surface area at top of sludge blanket, $ft^2$ | 8.25 | |

## TABLE 7. A.C. LAWRENCE LEATHER COMPANY WASTEWATER PILOT PLANT
(Continued)

| Characteristic | Design Factor | Operating Range Tested |
|---|---|---|
| Flow | 5.0 | 4.0 -15.0 |
| Surface overflow rate, gpd/ft$^2$ | 510.0 | 410 -1,530 |
| Detention time, hrs | 1.0 | 1.25-0.33 |
| Surface overflow rate at top of sludge blanket, gpd/ft$^2$ | 870.0 | 700 -2,620 |
| Detention time in sludge blanket, min | 25.0 | 31 -8.3 |

### AERATION BASIN

Cylindrical, flat bottom, "Cavitette" aerators.

| Characteristic | Design Factor | Operating Range Tested |
|---|---|---|
| Diameter, ft | 8.0 | |
| Liquid depth, ft | 4.0 | |
| Volume, gals | 1,500.0 | |
| Aerators, number | 3.0 | |
| Horsepower, each | 1.0 | |
| Flow | | |
| Tannery wastewater, gpm | 2.0 | 0.0-5.0 |
| Sanitary sewage, gpm | 1.0 | 0.5-2.5 |
| Return sludge, gpm | 1.0 | 1.0-3.0 |
| Total, gpm | 4.0 | 2.0-9.5 |
| Detention Time | | |
| Based on wastewater and sanitary sewage, hrs | 8.3 | 12.5-3.3 |
| Based on total flow, hrs | 6.3 | 8.3-2.6 |
| BOD loading, lbs/day/1,000 cu ft | 130.0 | 6.0-300 |

### SECONDARY SEDIMENTATION BASIN

Cylindrical, conical bottom, center submerged baffled inlet, weir overflow outlet.

| Characteristic | Design Factor | Operating Range Tested |
|---|---|---|
| Diameter, ft | 4.0 | |
| Side water depth, ft | 4.0 | |
| Center depth | 6.0 | |
| Surface area, ft$^2$ | 12.5 | |
| Volume, gals | 435.0 | |

TABLE 7. A.C. LAWRENCE LEATHER COMPANY WASTEWATER PILOT PLANT
(Continued)

| Characteristic | Design Factor | Operating Range Tested |
|---|---|---|
| Flow | | |
| Tannery waste plus sanitary sewage, gpm | 3 | 2.0 -7.5 |
| Tannery waste plus sanitary sewage plus return sludge, gpm | 4 | 3.0 -9.5 |
| Surface Overflow Rate, gpd/ft$^2$ | | |
| Based on tannery waste plus sanitary sewage | 345 | 230-865 |
| Based on total flow plus return sludge | 460 | 345-1,100 |
| Detention Time, hrs | | |
| Based on tannery waste plus sanitary sewage | 2.4 | 3.6 -0.97 |
| Based on total waste flow plus return sludge | 1.8 | 2.4 -0.76 |
| CENTRIFUGE | | |
| Solid bowl, continuous flow. | | |
| Bowl diameter, in. | 6.0 | |
| Speed, rpm | 3,000<br>4,000<br>5,000 | |
| Feed rate, gpm | 2.0 | 1.94-1.48 |
| Solids feed rate, lbs/hr | | 20-60 |

December 18, through December 28, 1967 - Initial operation of the pilot plant began on December 18, 1967. Initially, sanitary sewage was added to the aeration tank and the aerators placed in operation. The purpose of this action was to develop an activated sludge. Also during this period, adjustments were being made to the carbonation tank, the tannery waste pumping system, and the various metering pumps. At this time, there was no primary sedimentation basin because the need for this basin was not known. During this initial period, the operators were being trained in their duties.

December 29, 1967 through January 23, 1968 - During this period, the activated sludge unit continued to treat only sanitary sewage. The carbonation sedimentation unit was placed in operation treating the mixed acid and alkaline tannery wastes but no $CO_2$ or stack gas was used. The purpose of this operation was to determine the effectiveness of the basin as a primary sedimentation unit.

January 24, through February 8, 1968 - The aeration unit continued to treat sanitary sewage. However, a small amount of the effluent from the carbonation-upflow-sedimentation basin was added to the aeration basin influent. The addition of the settled tannery wastes to the aeration unit was not continuous because of operational problems with the carbonation system.

February 9, through February 15, 1968 - The activated sludge unit continued to treat sanitary sewage and small amounts of effluent from the carbonation upflow-sedimentation unit. During this period, carbonation was carried out using a mixture of compressed air and bottled $CO_2$. Also during this period and throughout the rest of the pilot plant work, the acid waste was diluted to a standard average strength.

February 16, through March 12, 1968 - At the beginning of this period, the stack gas compressor was installed and placed in operation. The alkaline feed to the carbonation upflow-sedimentation unit was therefore carbonated using stack gas. The rate of feed from the carbonation-upflow-sedimentation unit to the aeration unit was increased.

March 13, through March 25, 1968 - A series of special tests was made on the carbonation-upflow-sedimentation unit. The purpose of these special tests was to determine the amount of sludge removed by this unit at different flow rates.

March 26, through April 2, 1968 - The plant was operated at various flow rates to determine the best rate for good treatment. During this period the treatment consisted of mixing the alkaline and acid wastes, carbonation and upflow-sedimentation, aeration and secondary sedimentation. Foaming in the activated sludge unit was an operational problem encountered during this period.

April 3, through April 5, 1968 - During this period, excess sulfide in the form of a strong solution of technical sodium sulfide used by the tannery was added to the flow entering the aeration tank. The purpose of this test was to study the effect on the biological action and degree of treatment effected by the activated sludge unit under shock loading of sodium sulfide.

April 6, through April 23, 1968 - During this period, the pilot plant was shut-down, except for the aeration basin and the secondary sedimentation basin which continued to treat sanitary sewage in order to maintain the activated sludge mass. The pilot plant was shut down for the purpose of installing the primary sedimentation basin and to make other alterations in the system.

April 24, through June 1, 1968 - The pilot plant was placed back into operation with the primary sedimentation preceeding the carbonation-upflow-sedimentation basin in the flow pattern. The plant was operated at a variety of flow rates to study the effects of detention time, overflow rate, and mixed liquid suspended solids concentration on the efficiency of the treatment processes.

June 2, through June 8, 1968 - Sludge dewatering by centrifuge was investigated.

June 2, through June 17, 1968 - The results of the operation of the pilot plant to date were carefully studied and rates of flow estimated to yield the highest possible degree of treatment were applied to each unit during this period of the testing program.

June 18, through June 23, 1968 - Studies and analyses of the waste indicated that the concentration of phosphate contained therein was less than the theoretical optimum of phosphate required for the activated sludge process. During this period of operation, phosphate in the form of sodium phosphate was added to the wastes entering the activated sludge unit to determine if an increase in the phosphate concentration would, in fact, increase the efficiency of treatment.

June 24, through June 28, 1968 - One of the possible causes in the foaming in the aeration tank was the detergent used in the tannery for the purpose of hair washings. In order to test this thesis, appropriate doses of the detergent were added continuously to the activated sludge unit. The phosphate added during the previous period was continued during this time.

June 29, through July 8, 1968 - The plant was continued in operation at the theoretical optimum rate of flow with the continued addition of phosphate. No detergent was added during this period.

July 9, through July 12, 1968 - In order to determine whether or not chromium exerted a toxic effect on the biological system, a solution of the chromium mixture used in the tanning process was added directly to the aeration basin. During each succeeding 24-hour period, the rate of addition of chromium was increased. During this period of testing, the addition of extra phosphate continued. The pilot plant was shut-down at the end of the work period on July 12.

July 13, through July 20, 1968 - The pilot plant was drained and cleaned out and equipment packed for storage.

## RESULTS OF PILOT PLANT OPERATION

### General

The pilot plant was operated in four general phases. The first phase, December 18, 1967, through February 15, 1968, was the break-in phase when the operators were learning how to operate the plant and working out the bugs. The second phase, February 16, 1968 through April 5, 1968, was the initial period when operating data were being collected. During this period, the results of the operation were not entirely satisfactory. The plant effluent quality was higher in BOD and suspended solids than was desired and the results were erratic. The causes of this erratic performance were felt to be fluctuations in the quality of the influent tannery wastes and difficulty in the control of carbonation because of rapid changes in influent alkalinity.

The pilot plant was, therefore, shut-down, except for the activated sludge which was sewage fed, from April 6, through April 23, to permit the installation of a primary sedimentation basin ahead of the carbonation-sedimentation basin. The primary sedimentation served to equalize the fluctuations in quality as well as to remove a large proportion of the settleable solids.

On April 24, the pilot plant was placed back in full operation with the primary sedimentation basin in the flow line. Each week during May, the rate of flow through the plant was increased as follows:

| Date<br>May, 1968<br>From | To | Flows, gpm<br>Primary Influent | Carbonation Influent | Activated[1] Sludge Influent |
|---|---|---|---|---|
| 1 | 11 | 6.25 | 5 | 5 |
| 13 | 18 | 10 | 7 | 6.5 |
| 20 | 25 | 15 | 10 | 8 |
| 27 | 1 | 20 | 6 | 9.5 |

Note[1] Includes sanitary sewage and a return sludge flow of 2 gpm

The results of the operation during May became erratic when the flow to the activated sludge unit increased above 1 gpm of sanitary sewage, 2 gpm of tannery waste and 2 gpm of return sludge (a total of 5 gpm). On June 1, the flow to the processes were reduced between 5.25 and 6.0 gpm to the primary, 4.5 to the carbonation-sedimentation basin and a total of 4.5 gpm to the secondary system consisting of 0.5 gpm sanitary sewage, 2.0 gpm return sludge. These flows were continued throughout the remainder of the pilot plant operation. The flows employed for testing during June and July were selected because previous experience indicated that maximum removal of BOD and other pollutants could be obtained while at the same time maintaining a stable system. This was demonstrated by the four weeks operation in June, 1968, during which time the effluent BOD exceeded 50 mg/l only on two occasions and the average BOD was 32 mg/l.

## BOD Removal

Fig. 6 is a chronological record of the removal of BOD in the pilot plant. The upper line in Fig. 6 represents the 5-day, 20°C BOD analyses of the pilot plant influent and the lower line represents the BOD analyses for the pilot plant effluent. Notes on Fig. 6 are guides to the operating procedures being followed at any particular time. The results reported on Fig. 6 represent the analyses of 24-hour composite samples. The pilot plant operators collected samples from the influent to the leading pilot plant unit after the alkaline and acid wastes had been mixed. Samples were also collected from the effluent of the primary sedimentation basin, the effluent from the carbonation-upflow-sedimentation basin, and the effluent from the secondary sedimentation basin. The samples were collected approximately once each hour. Since the flow through the pilot plant was constant, equal volumes of samples were taken for making up the composite.

The results reported on Fig. 6 indicate the wide fluctuations in the quality of the pilot plant influent. The tanning influent BOD ranged from a low of about 500 mg/l to a maximum of about 3,600 mg/l. The wide fluctuations in influent BOD could not be specifically associated with any particular operations in the tannery.

The effluent BOD was dependent to a considerable extent upon the rate of flow and the manner in which the pilot plant was operated. When only sanitary sewage was being treated in the secondary system at the beginning of the pilot plant work, the detention times in the aeration basin were about 9 hours. The long aeration period resulted in a hard-to-settle floc and somewhat irregular results. When the plant was more heavily loaded by the addition of tannery wastes starting about February 9, the effluent BOD concentration continued to fluctuate over a wide range in a non-acceptable manner. Following installation of the primary sedimentation basin, the operation of the secondary system improved greatly.

Following the installation of the primary sedimentation basin, the secondary system was operated initially at the rate of about 3 gpm. The influent consisted of about 1 gpm of sanitary sewage and 2 gpm of carbonation basin effluent. After about 2 weeks the flows were increased to 4.5 gpm maintaining the ratio of sanitary sewage to carbonation basin effluent at 1 to 2. After about a week at this rate, the flow was increased to about 6 gpm. After about one week at 6 gpm the flow was increased to 7.5 gpm. The results shown in Fig. 6 indicate that when the flow of sanitary and tannery waste exceeded 3 gpm, (May 13, - June 1), the concentration of BOD in the effluent tended to become somewhat erratic.

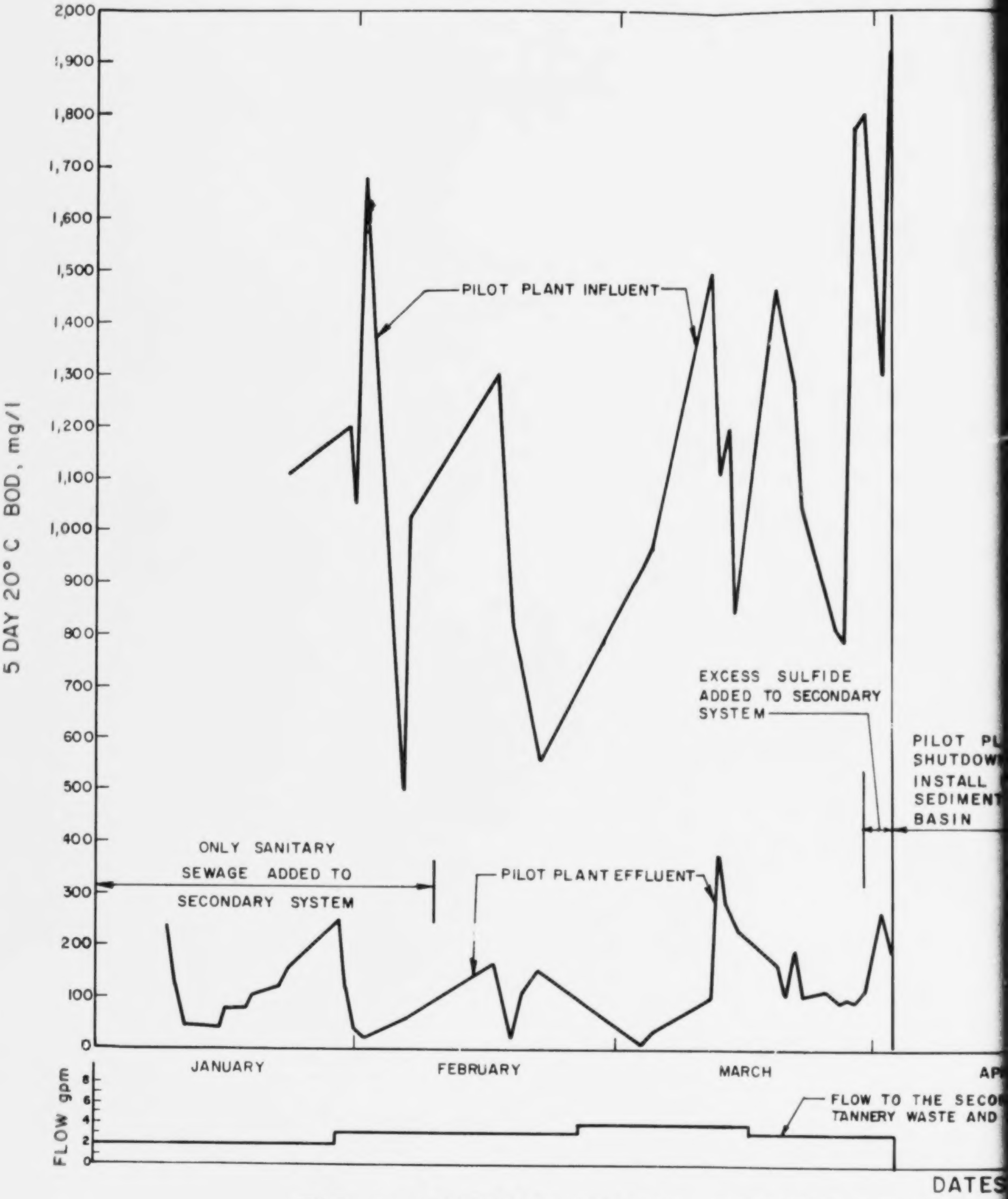
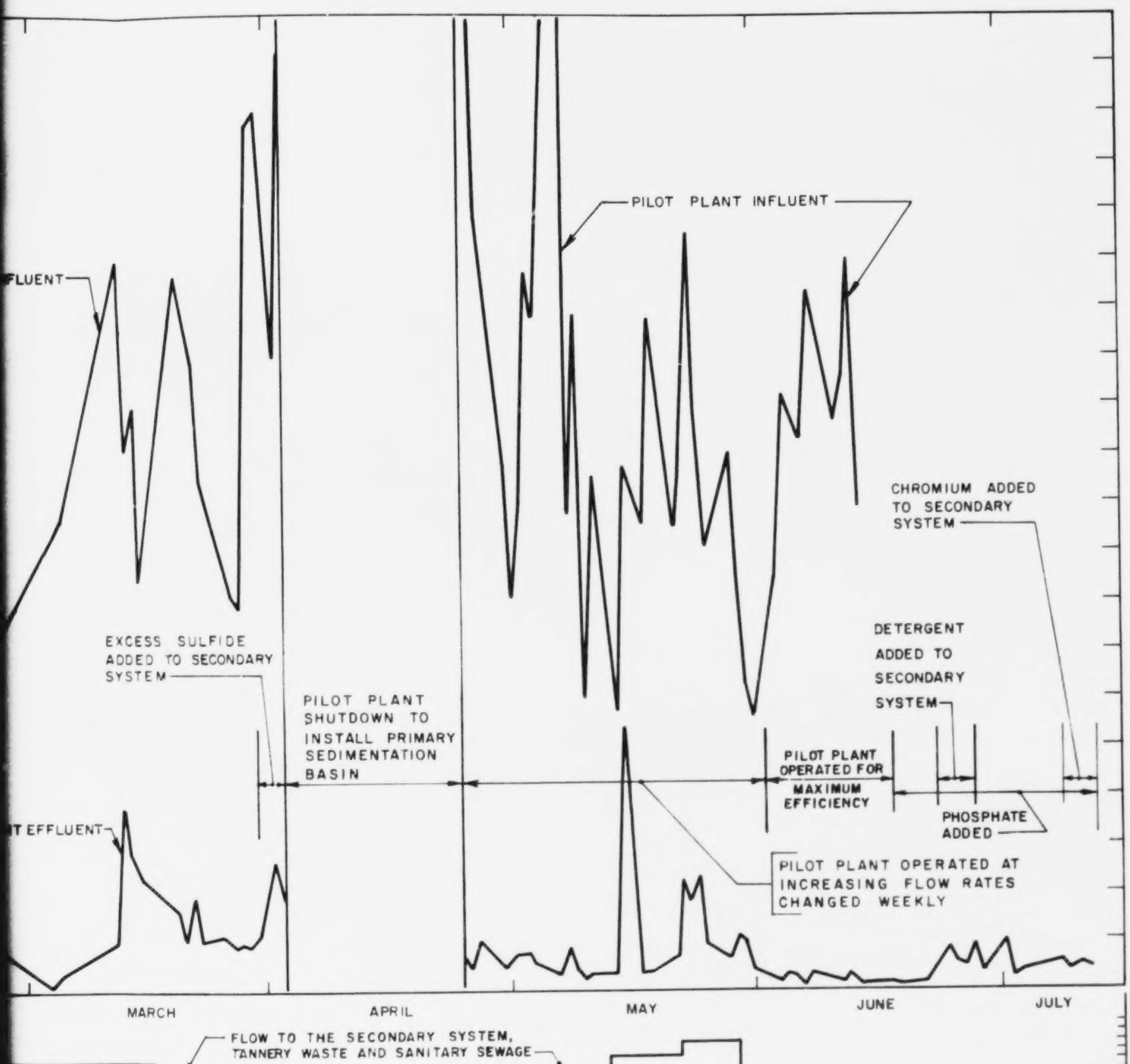


FIG. 6 CHRONOLOGICAL RECORD OF BOD



GICAL RECORD OF BOD IN PLANT INFLUENT AND EFFLUENT

Throughout the months of June and July, the pilot plant secondary system was operated at a rate of 2.5 gpm. The influent consisted of 0.5 gpm of sanitary sewage and 2.0 gpm of carbonation basin effluent. The results obtained during this period were excellent with the highest BOD in the effluent during this time being 93 mg/l and the lowest 14 mg/l. The average BOD was about 32 mg/l.

Near the end of June a non-ionic detergent used in the tannery for hair-washing was added to the secondary system in concentrations ranging from 10 to 40 mg/l in an attempt to determine the effect of the detergent on foam generation in the secondary system. The results on Fig. 6 indicate the effluent BOD increased to an average about 25 mg/l. But there was no significant increase in the foaming.

During the last week in June, solutions of chromium used in the tanning process were added to the secondary system in an attempt to determine the effects of high chromium concentrations on the activated sludge process. Each day for four days, the amount of chromium added to the secondary system was increased. As may be seen from the results on Fig. 6 for the end of July, little if any change could be detected as a result of the chromium addition. The toxicity of chromium to activated sludge is discussed in greater detail later in this report. Fig. 6 does not indicate the individual processes in which BOD was removed.

Fig. 7 is a plot of the percentage removal of BOD. The upper line represents the percentage removal in the pilot plant as a whole and the lower line represents the percentage removal in the primary system (carbonation-upflow-sedimentation basin only before April 5; primary sedimentation basin followed by carbonation-upflow sedimentation after April 24). The percent removal for the plant as a whole was computed from the total weight of BOD in the tannery waste and in the municipal sewage and from the total effluent BOD. As may be seen from Fig. 7, the percentage removal of BOD in the primary system was erratic; however, the overall BOD removal for the pilot plant was good, rarely falling below 90 percent, and then only when the plant was over-loaded i.e., the middle of May.

Studies of the individual processes and their efficiency in removing BOD is discussed in a following section of the report. We may conclude, however, from the results shown on Figs. 6 and 7 that if the pilot plant is operated at a rate of flow not exceeding about 3 gpm, and with a flow of sanitary sewage of at least 0.5 gpm an extremely high degree of treatment (in excess of 95 percent) removal of BOD can be obtained regardless of fluctuations of the plant influent quality.

## Removal of BOD by the Primary System

From February 9, 1968, to April 5, 1968, the carbonation basin served as both a primary sedimentation and a carbonation basin. Overloading with sludge occurred, making proper operation difficult. Furthermore, rapid fluctuations in influent pH and alkalinity made accurate control of carbonation impractical. Hence, on April 24, 1968, primary sedimentation in

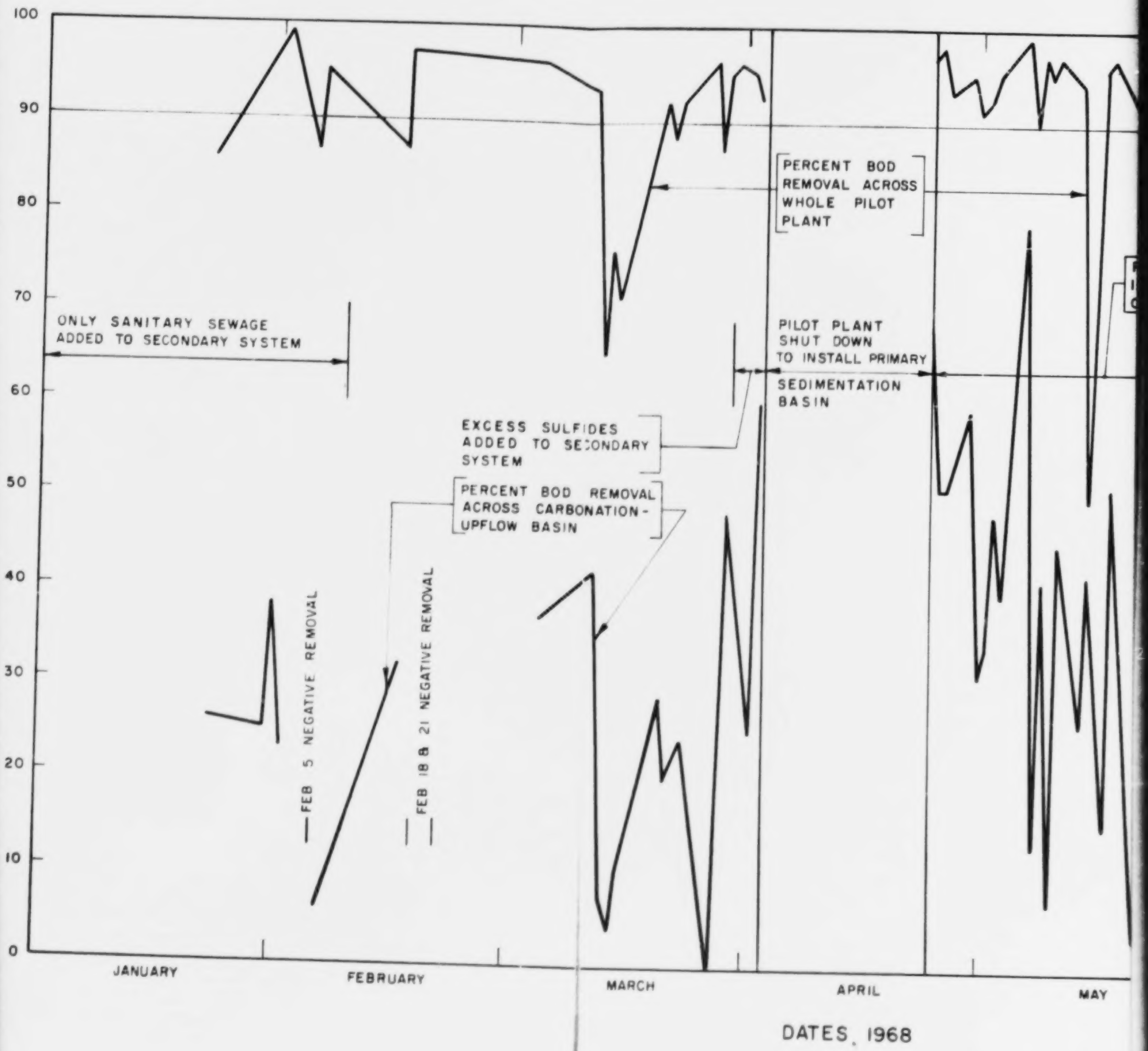
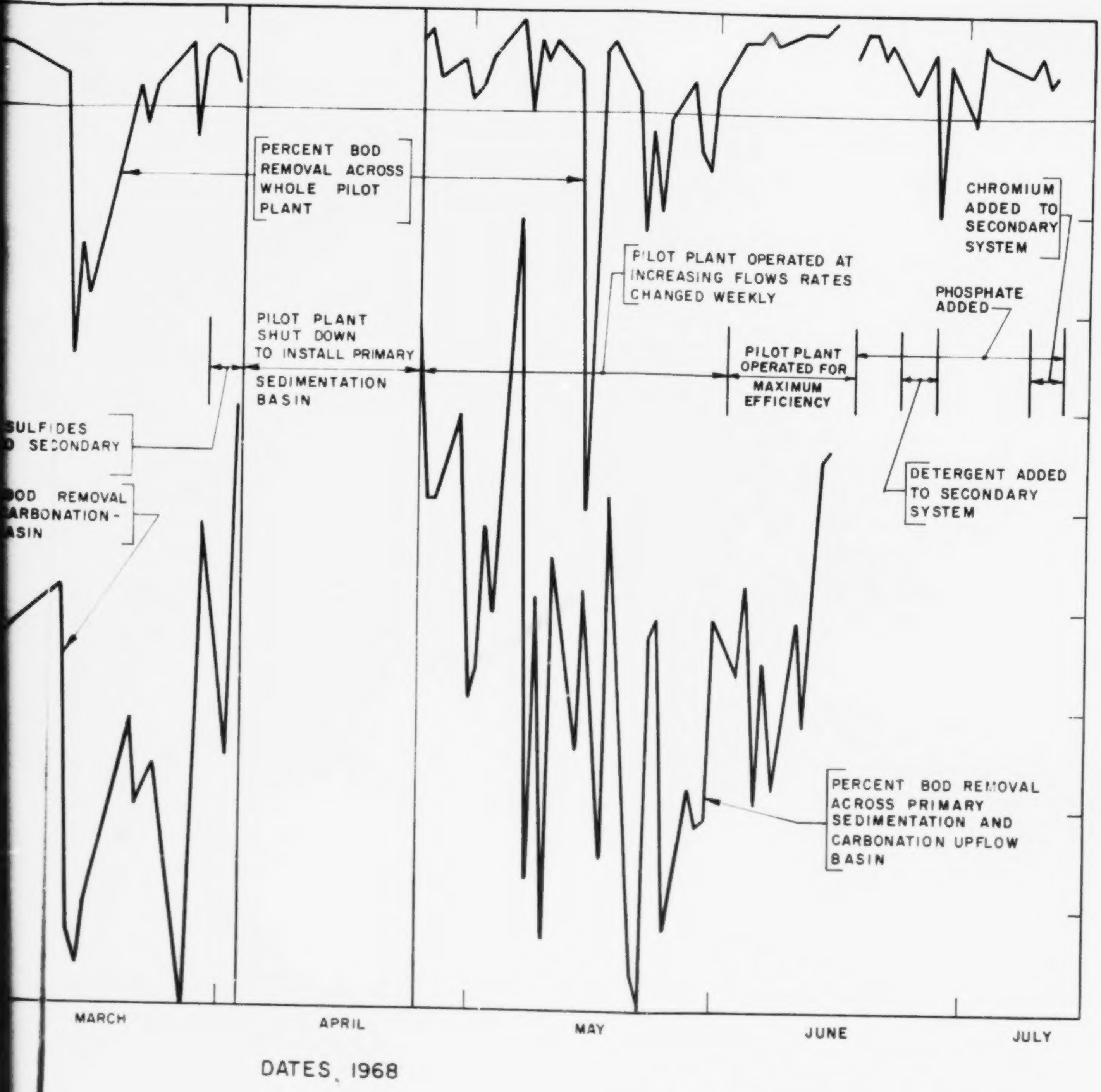


FIG. 7 CHRONOLOGICAL RECORD OF BOD REM



CHRONOLOGICAL RECORD OF BOD REMOVAL

a separate basin was installed ahead of the carbonation basin and used until the end of the testing period. Therefore, removal of settleable solids and settleable BOD by the primary section of the plant took place in a combined carbonation-sedimentation basin prior to April 5, and subsequent to April 24, in a separate primary sedimentation basin followed by the carbonation-sedimentation basin.

The results of BOD removal in the primary sedimentation basin are shown in Fig. 8. In Fig. 8, the "Percent Removal of BOD" is plotted as a function of "Surface Overflow Rate." The circled points represent the analyses of daily composite samples. The line is the line of best fit based on the least-squares method of fitting all of the data. On a few occasions negative results were obtained, i.e., the effluent BOD was higher than the influent. The negative results were not used in fitting the line to the data. See "Suspended Solids" on page 67 for explanation of negative results.

The data show that on the average about 30 percent of the BOD in the tannery wastewaters will be removed by the primary sedimentation at an overflow rate of 500 gpd/ft . The variability of the resultant removal reflects the variability in the quality of the influent wastes and illustrates the need for equalization to reduce these fluctuations and thereby improve the operation of succeeding treatment processes.

The low percentage removal of BOD by primary sedimentation at times reflects the periods of low settleable solids concentration in the influent wastes. Reference is made to the waste surveys, Figs. A-5 and A-6 which show a range of settleable solids concentration from more than 750 ml/1 to less than 25 ml/1. Normally following primary sedimentation, the settleable solids were less than 5 ml/1. It should be noted that the percent removal is dependent upon the total influent concentration as well as the effluent concentration, which may be a relatively constant minimum value regardless of the influent concentration.

The results of the primary sedimentation basin studies appear to indicate that on the average the settleable BOD comprises about 40 percent of the total BOD in the waste from the tannery.

Removal of BOD by the combined carbonation-sedimentation basin is shown as a function of surface overflow rate in Fig. 9. The results may be dividied into two periods. The first was the period when the basin served as both a primary sedimentation basin and carbonation basin and the second period when the carbonation basin was preceded by the separate primary sedimentation basin.

During the first period, the BOD removal was very similar to that obtained in the primary basin as is shown by the upper line on Fig. 9. As might be expected, BOD removal by the carbonation-sedimentation basin alone was about 50 percent lower following the installation of the primary sedimentation basin, since the bulk of the settleable solids had already been re-

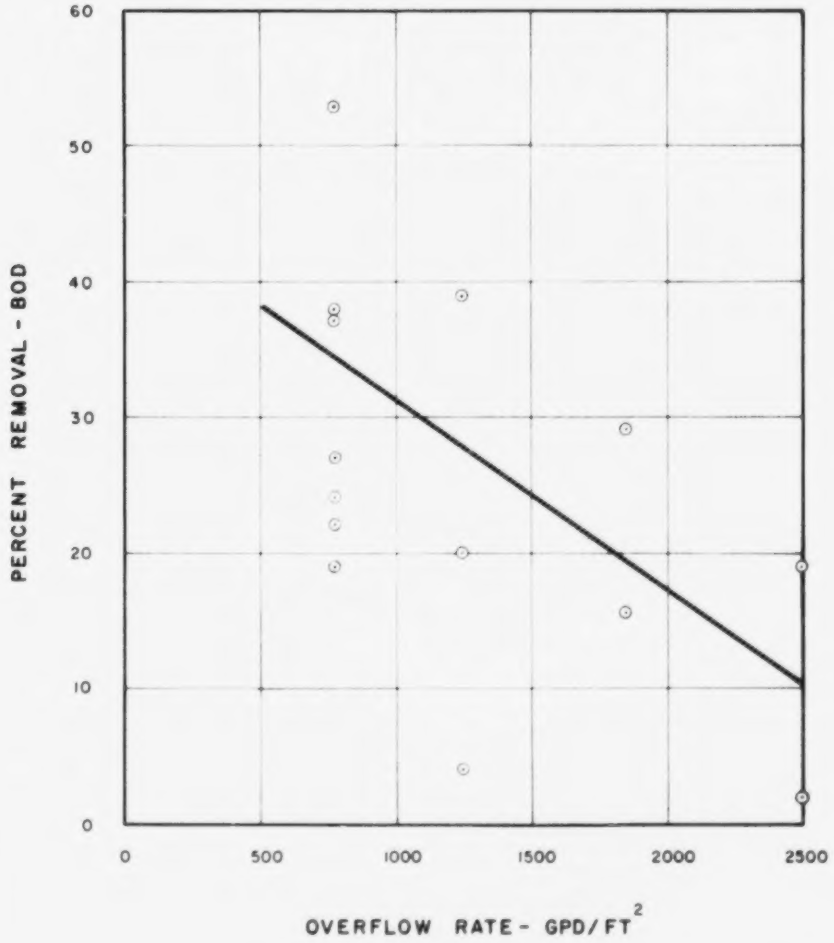


FIG. 8 BOD REMOVAL VS. OVERFLOW RATE
PRIMARY SEDIMENTATION BASIN

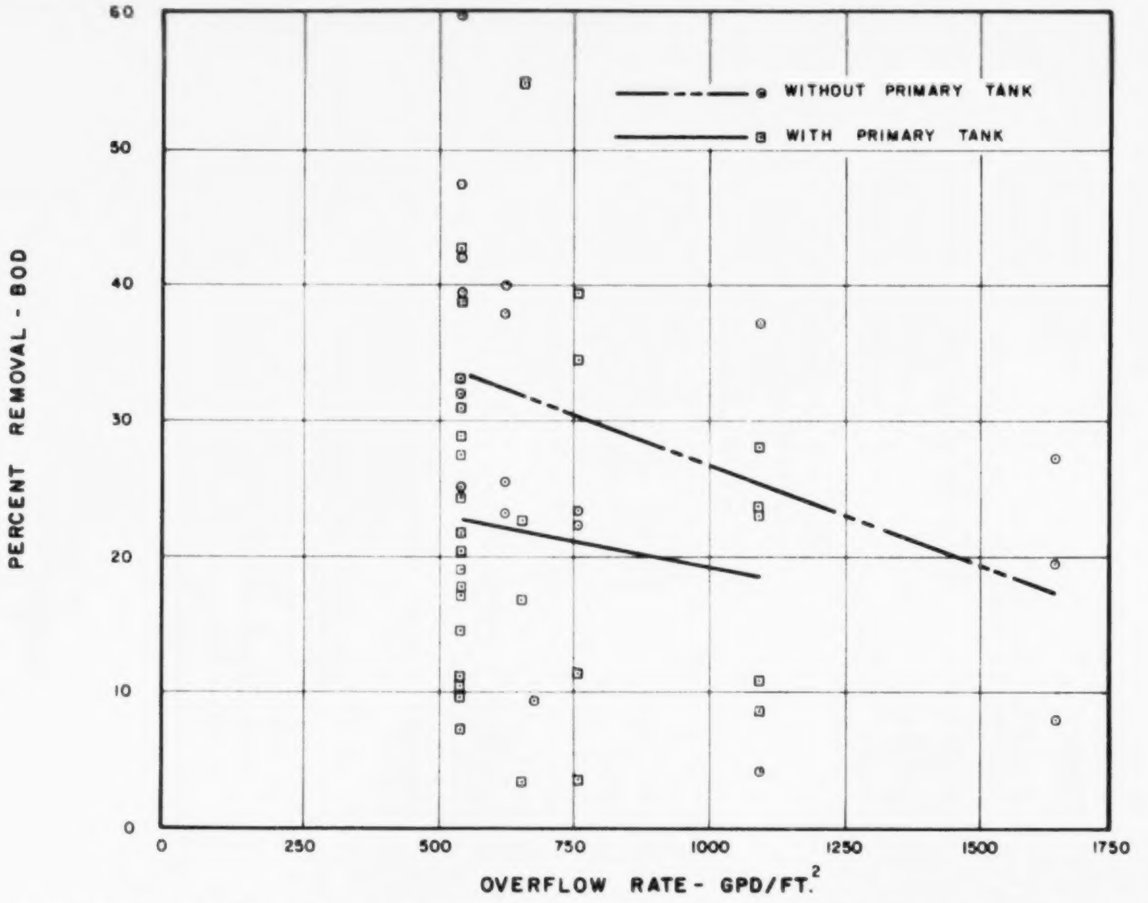


FIG. 9 BOD REMOVAL VS. OVERFLOW RATE - CARBONATION SEDIMENTATION BASIN

moved. However, the overall removal of BOD by the two basins in series was higher than for either basin alone. At an overflow rate of 500 gpd/ft the average rate of removal of BOD in the carbonation-sedimentation basin alone was 34 percent. The removal in the carbonation-sedimentation basin following the primary sedimentation basin was 23 percent and the overall BOD removal by both basins in series was 52 percent.

The overall improvement in BOD removal (i.e., more than 40 percent) is attributed to:

1. The effects of coagulation by precipitated calcium carbonate and chromium hydroxide.

2. Longer detention period provided by the two basins in series.

3. The effects of equalization in the primary sedimentation basin which permitted more effective carbonation in the carbonation basin, which resulted in the precipitation and removal of some dissolved solids.

4. Smaller sludge volumes in the carbonation-sedimentation basin following primary sedimentation. These smaller accumulations of sludge reduced the carryover from the carbonation basin.

Removal of BOD by the Secondary System

As expected the greatest removal of BOD was accomplished by the activated sludge system. Fig. 10 summarizes the results of BOD removal by the activated sludge system alone. The results in Fig. 10 do not include any removals obtained in the primary system. In Fig. 10, the percent removal of BOD is plotted as a function of the ratio of "Mixed Liquor Volatile Suspended Solids" to the "Influent BOD."

The activated sludge process depends upon a complex relationship between the concentration of biota present in the system, the concentration of organic material suitable as food for the bacteria and the time available for the biological oxidation reactions to take place. The biomass concentration may be estimated from the mixed liquor volatile suspended solids, the available food from the BOD and the time from the ratio MLVSS to BOD. Experience with activated sludge has shown that approximately 0.5 to 1.0 hours contact time between the waste and the activated sludge is needed for the sludge to absorb the food. About 0.5 to 3.0 days (Gould's sludge age) of aeration of the sludge is needed to complete the biological reactions. In the completely mixed system used in the pilot plant the food absorption and oxidation phases of the reaction occur simultaneously in the mixed liquor aeration basin. Sludge detention time is related to the sludge concentration and BOD by a complex but largely self-regulating relationship.

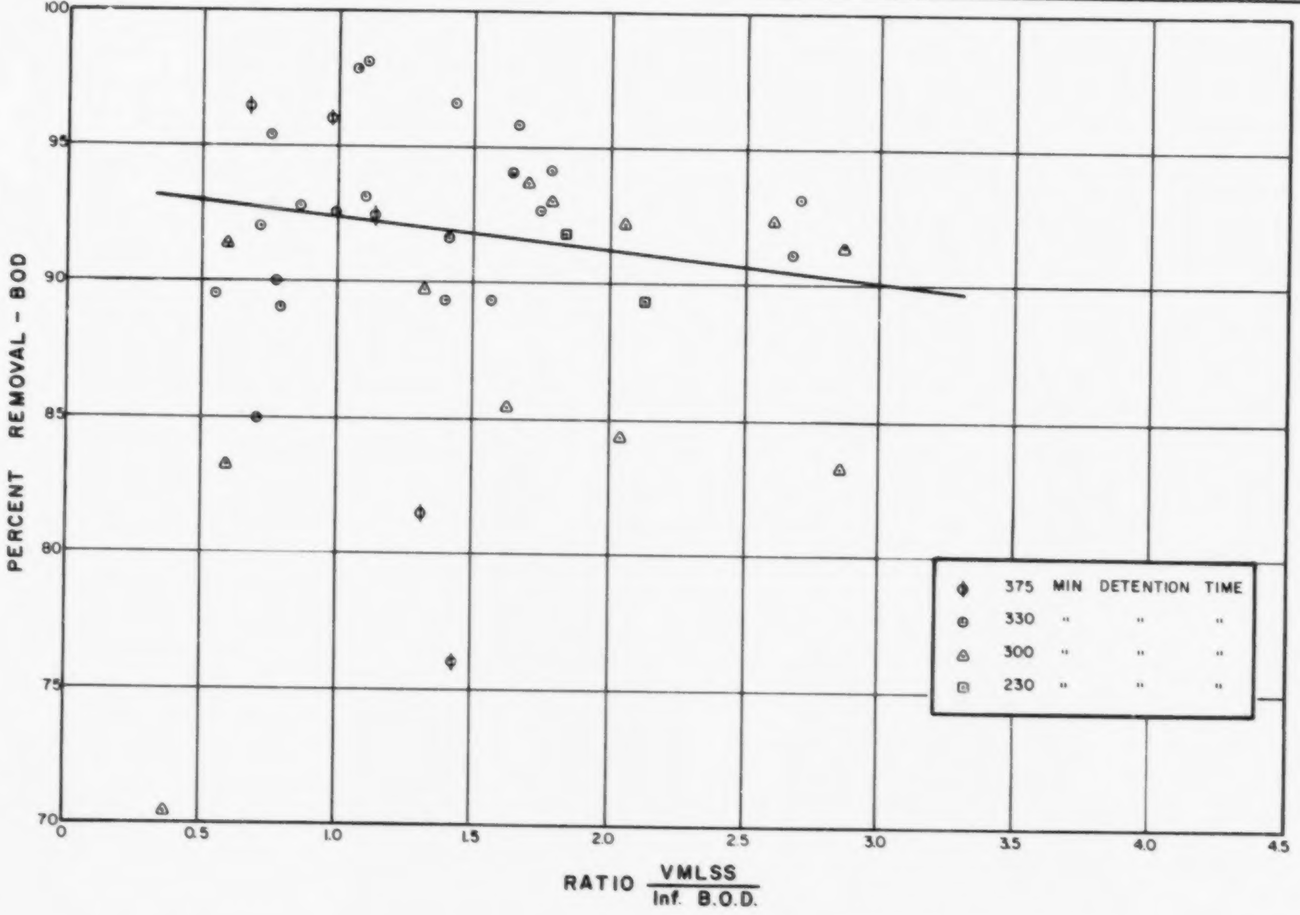


FIG. 10 REMOVAL OF B.O.D AS A FUNCTION OF MIXED LIQUOR SUSPENDED SOLIDS

The line on Fig. 10 is the line of best fit for detention times between 230 minutes and 375 minutes. Data for detention times less than 230 minutes were not used in plotting the line of best fit because they were not representative of the design recommended by this report. The BOD in the influent includes the BOD in the untreated sanitary sewage from Norway, Maine and the effluent from the pilot plant carbonation-sedimentation basin.

From Fig. 10, it may be seen that the ratio of "Mixed Liquor Volatile Suspended Solids" to "Influent BOD" had little effect on the degree of removal of BOD by the secondary treatment process over the range of values tested. Thus, we may assume that the bacteria concentration was not a limiting factor in this range. At a MLVSS/Influent BOD ratio of 0.5 the average BOD removal was about 93 percent. These results indicate that over a wide range of MLVSS/Influent BOD ratios the efficiency of the process remained at a high level.

The time of aeration appears to be more important in determining the efficiency of the process. Those tests made with detention times less than 230 minutes yielded efficiencies of about 80 percent BOD removal. However, tests at these short detention times were limited to MLVSS/Influent BOD ratios of about 0.75. Higher ratios may have yielded increased efficiencies but no operating data are available to support any conclusions in this regard.

Data for long detention periods (i.e., in excess of 375 minutes), is limited to the start-up period of the secondary process, during which time only sanitary sewage was being treated. The results indicate that the efficiency of treatment was about 80 percent BOD removal during this time. The relatively low efficiency was probably due to the lack of an active sludge mass during start-up as well as to the poor settling characteristics of the sludge. As soon as the efficiency increased, tannery waste was added and the proposed method of tannery wastes treatment was started.

## Secondary Sedimentation

The efficiency of the activated sludge is dependent to a considerable degree to the efficiency of the secondary sedimentation basin. It is necessary to separate the activated sludge solids from the treated waste before the effluent may be discharged to the receiving waters. The two conditions necessary for satisfactory separation are; a sludge which will settle readily and a properly designed and operated sedimentation basin.

Fig. 11 is a plot of the concentration of suspended solids in the effluent of the pilot plant secondary sedimentation basin as a function of overflow rate. The range of values for any particular overflow rate reflects in general, the settleability of the sludge on the day of the particular test, however, some points of low settleability were due to foam carry-over from

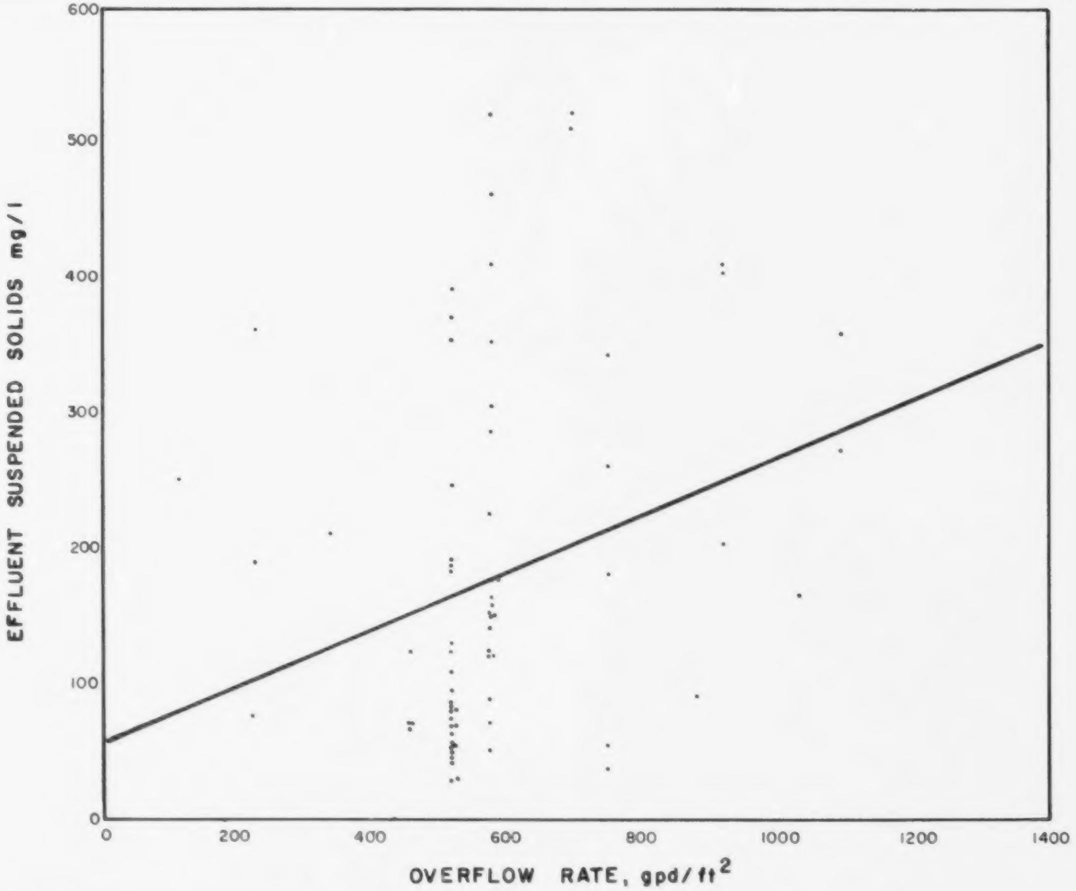


FIG. 11 SECONDARY EFFLUENT SUSPENDED SOLIDS VERSUS OVERFLOW RATE

The aeration basin. Fig. 13 presents the suspended solids in the plant effluent in a chronological order. From Fig. 13 it may be seen that during periods of good operation the average suspended solids concentration in the effluent were generally less than 200 mg/l. This corresponds to an overflow rate of about 500 gpm/ft$^2$ for the line on Fig. 11. Since the line on Fig. 11 is a line of best fit for all of the data it is weighted somewhat to a conservatively low overflow rate for secondary sedimentation.

It may be concluded from the results of these tests and these data that a mixture of sanitary sewage and partially treated tannery wastes of the type discharged at South Paris can be treated by the activated sludge process to remove more than 90 percent of the BOD influent to the process, if the operating conditions are maintained within the following ranges:

1. Ratio of MLVSS/Influent BOD between 0.5 to 3.0.
2. Time of aeration between 230 minutes and 375 minutes.
3. Overflow rate in the secondary sedimentation basin less than 500 gpd/ft$^2$. (Represented by flows of 2 gpm tannery wastes, 1 gpm sanitary sewage and 1 gpm return sludge).

## Solids Removal

Effluent surveys of the tannery indicated that the wastes contain large quantities of solids. The average settleable solids were estimated to be about 130,000 gallons per day, the total solids were estimated to be about 70,000 lbs per day and the suspended solids about 17,000 lbs per day. The average concentration of total solids, which entered the pilot plant between February 9, 1968 and the end of May, 1968, was 6,334 mg/l, or about 52,700 lbs per day based on a flow of 1 mgd. During the same time interval, the average concentration of total solids in the pilot plant effluent was about 2,200 mg/l equivalent to about 18,300 lbs per day based upon a daily flow of 1 mgd. The overall removal of solids through the pilot plant was therefore about 65 percent or about 34,400 lbs per day. However, it is difficult to pinpoint the unit processes in which various portions of the solids were removed.

Fig. 12 is a plot showing total solids in the pilot plant influent as the upper line and the total solids in the pilot plant effluent as the lower line. As may be seen from Fig. 12, the total solids in the pilot plant influent varied from a low of about 3,000 mg/l to a maximum of more than 10,000 mg/l. The total solids in the effluent varied from a high of about 5,000 mg/l to a minimum of slightly less than 1,000 mg/l. The total solids in the effluent depended somewhat on the proportion of sanitary sewage to tannery wastes. For this reason, the period prior to the installation of

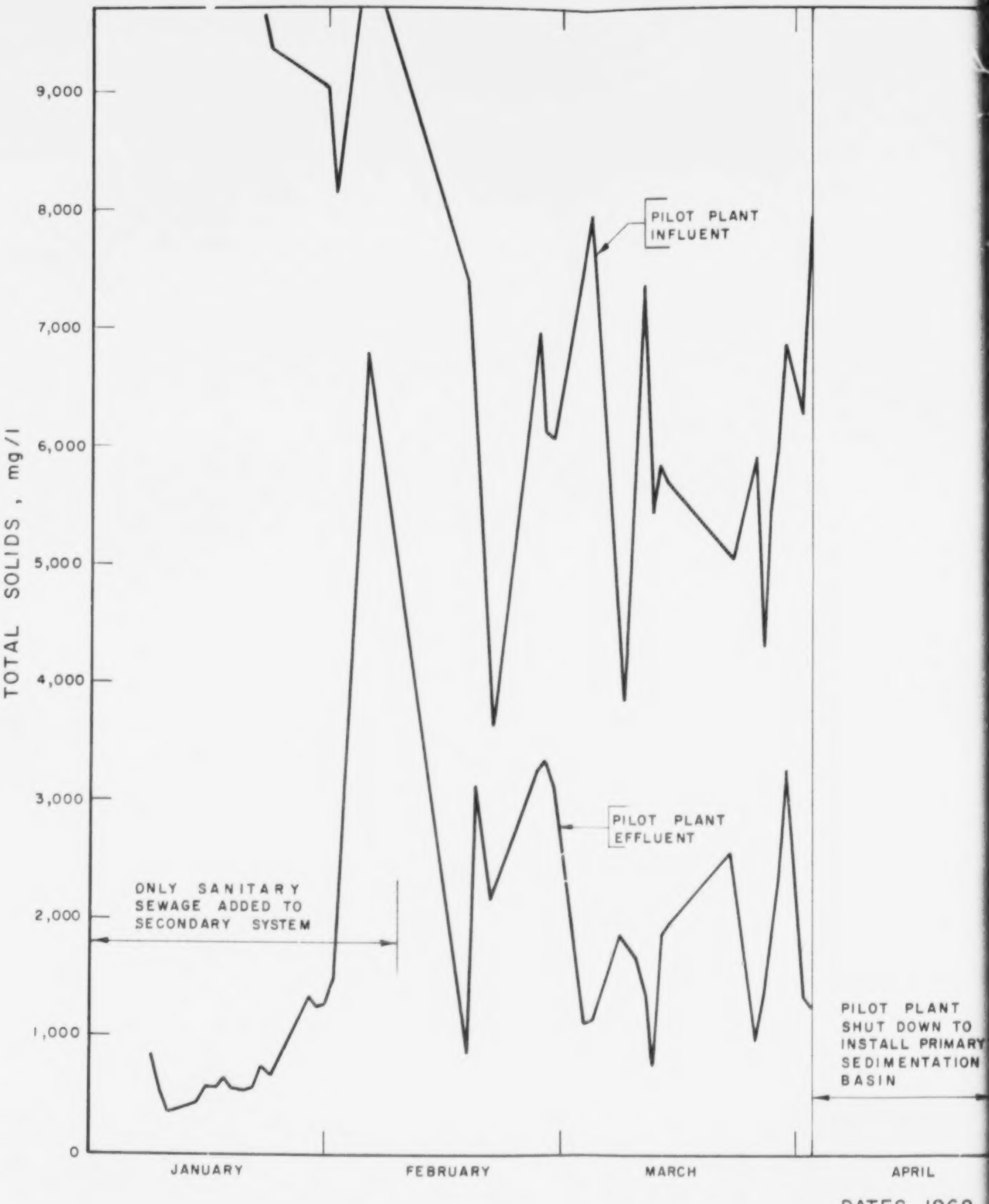
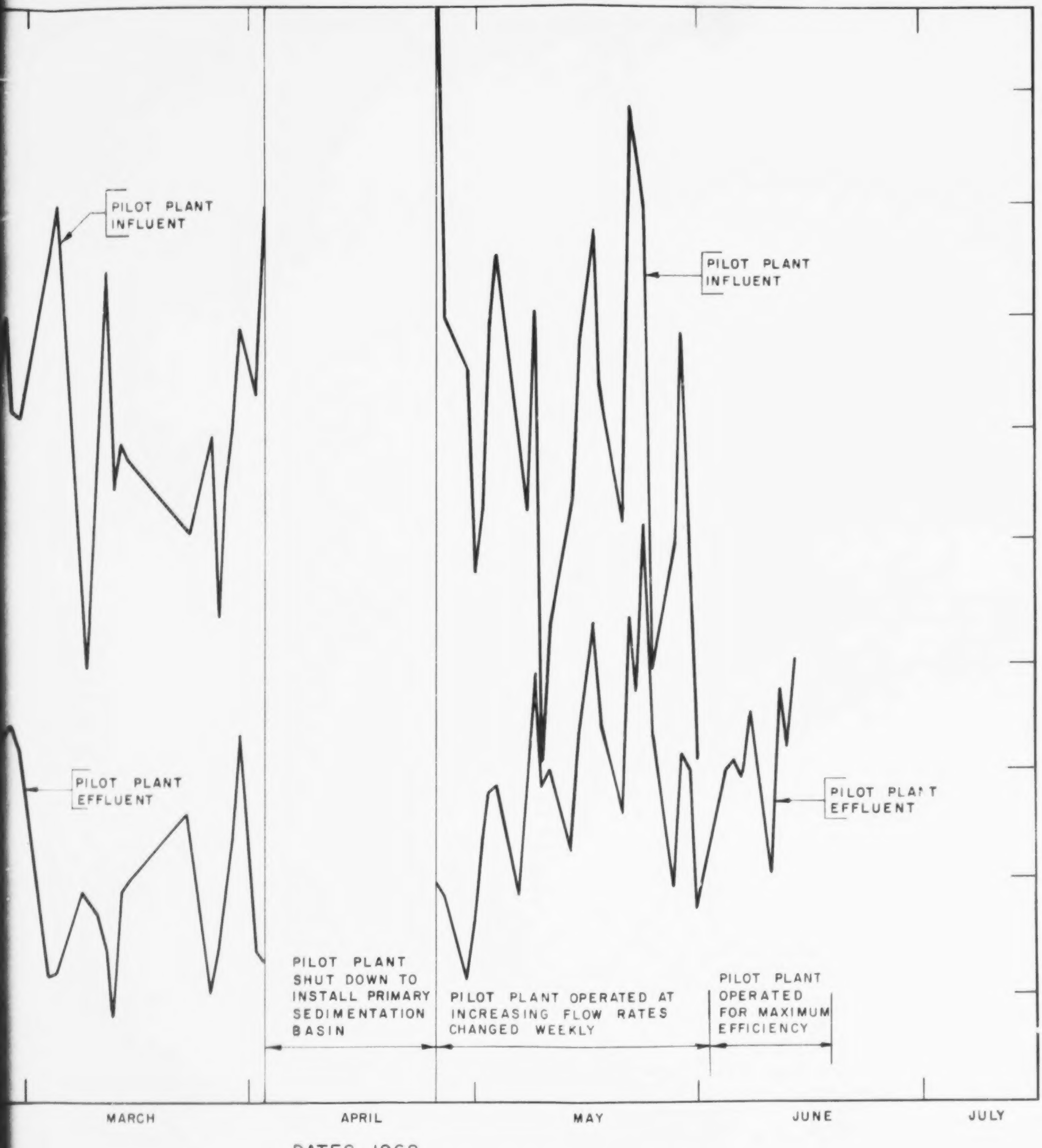


FIG. 12 CHRONOLOGICAL PLOT



CHRONOLOGICAL PLOT OF TOTAL SOLIDS

the primary sedimentation basin has a slightly lower total solids in the effluent than the period following the installation of the primary sedimentation basin. Prior to installing the primary sedimentation basin, the proportion of sanitary sewage to tannery wastes was higher than during the period following.

Part of the solids removed will be oxidized to carbon dioxide and water while the remainder will be removed as sludge which will require dewatering and disposal.

Fig. 13 is a chronological record of the suspended solids in the pilot plant influent and the effluent. The upper line on Fig. 13 represents the analyses of composite samples of the plant influent. The lower line represents composite samples of the plant effluent. As may be seen from Fig. 13, the suspended solids concentration varied from more than 3,600 to a minimum slightly less than 500 mg/l. The suspended solids in the pilot plant effluent varied in concentration from a maximum of about 600 to a minimum of about 30 mg/l. After the primary sedimentation basin was installed and the pilot plant was operating in a satisfactory manner, the suspended solids in the plant effluent averaged about 200 mg/l. During the middle and the end of May, when the pilot plant was being operated at excessively high rates of flow the average suspended solids increased to about 250 mg/l.

The average removal of suspended solids was about 75 percent on passage through the treatment process. The removal of suspended solids, in terms of percent removal, increased greatly during those periods of time that high suspended solids occurred in the pilot plant influent. It is significant to note from a pollution abatement point of view, that it should be possible to readily maintain a suspended solids concentration in the effluent of less than 100 mg/l at all times. A removal to this extent represents a removal of more than 95 percent of all of the suspended solids in the tannery waste.

The difficulty of identifying the particular unit processes responsible for the removal of solids from the waste arises because of the nature of the solids being removed and the variability of their occurrence in waste flows. The suspended solids in the waste furnish a specific example. During those times of the day when large amounts of acid waste discharges, the mixture of the two waste streams results in the precipitation of considerable amounts of chromium hydroxide. The chromium hydroxide precipitate forms gelatinous flocs which trap significant quantities of collodal material which normally would not settle. The resulting solids do, however, settle to the bottom of the sedimentation basin and are far in excess of the amount of solids which would have resulted if the acid and alkaline wastes were settled separately, as is the case when their discharges do not coincide. Therefore even with the same waste discharges, the amount of solids removed by sedimentation alone is quite variable and dependent upon the chance discharges of both types of waste. Samples of the wastes were collected hourly and composited for a 24-hour period. However, the suspended solids determined on the composite are not representative of the actual suspended solids entering the sedimentation units. They are only representative of the suspended solids which

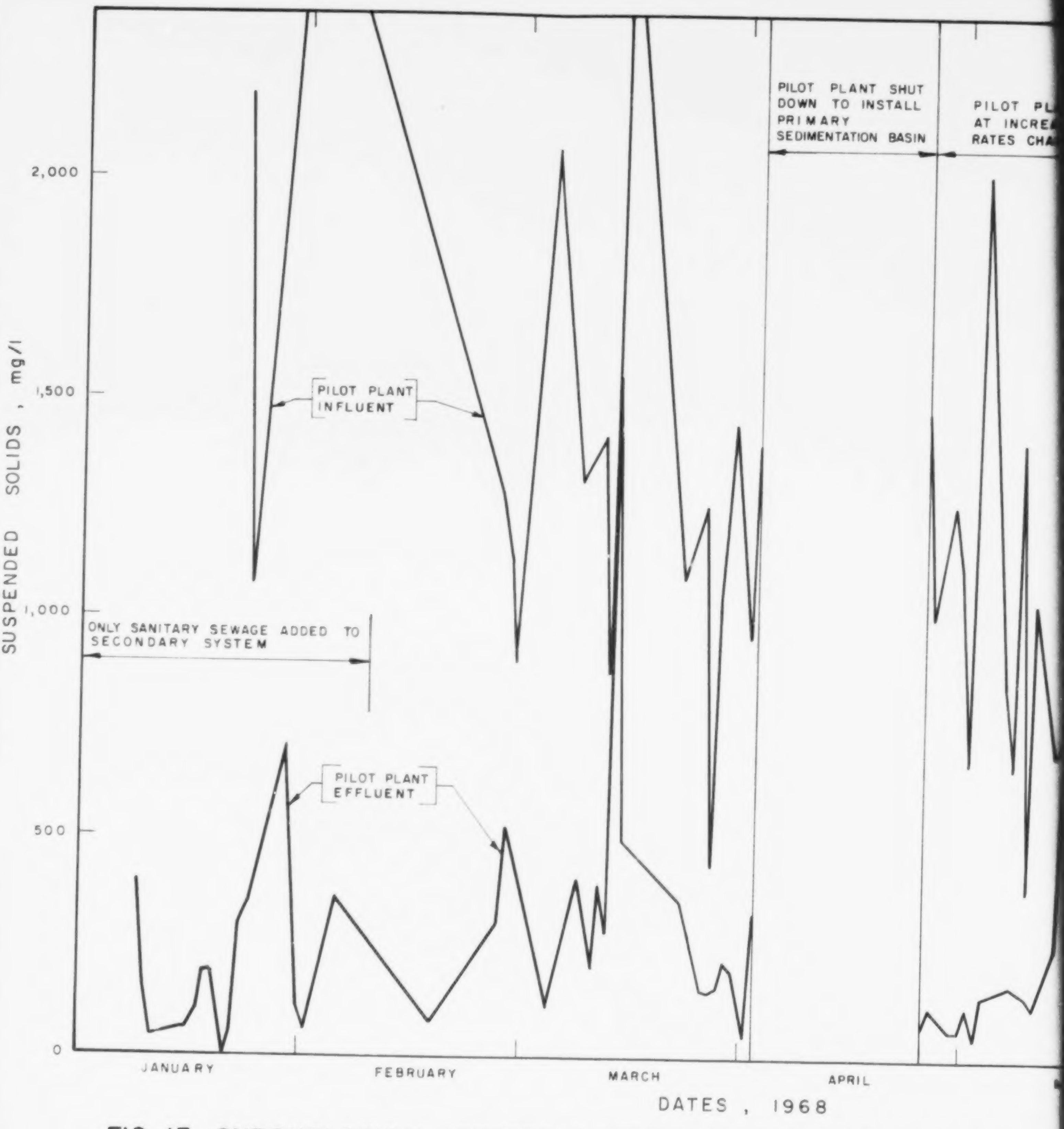
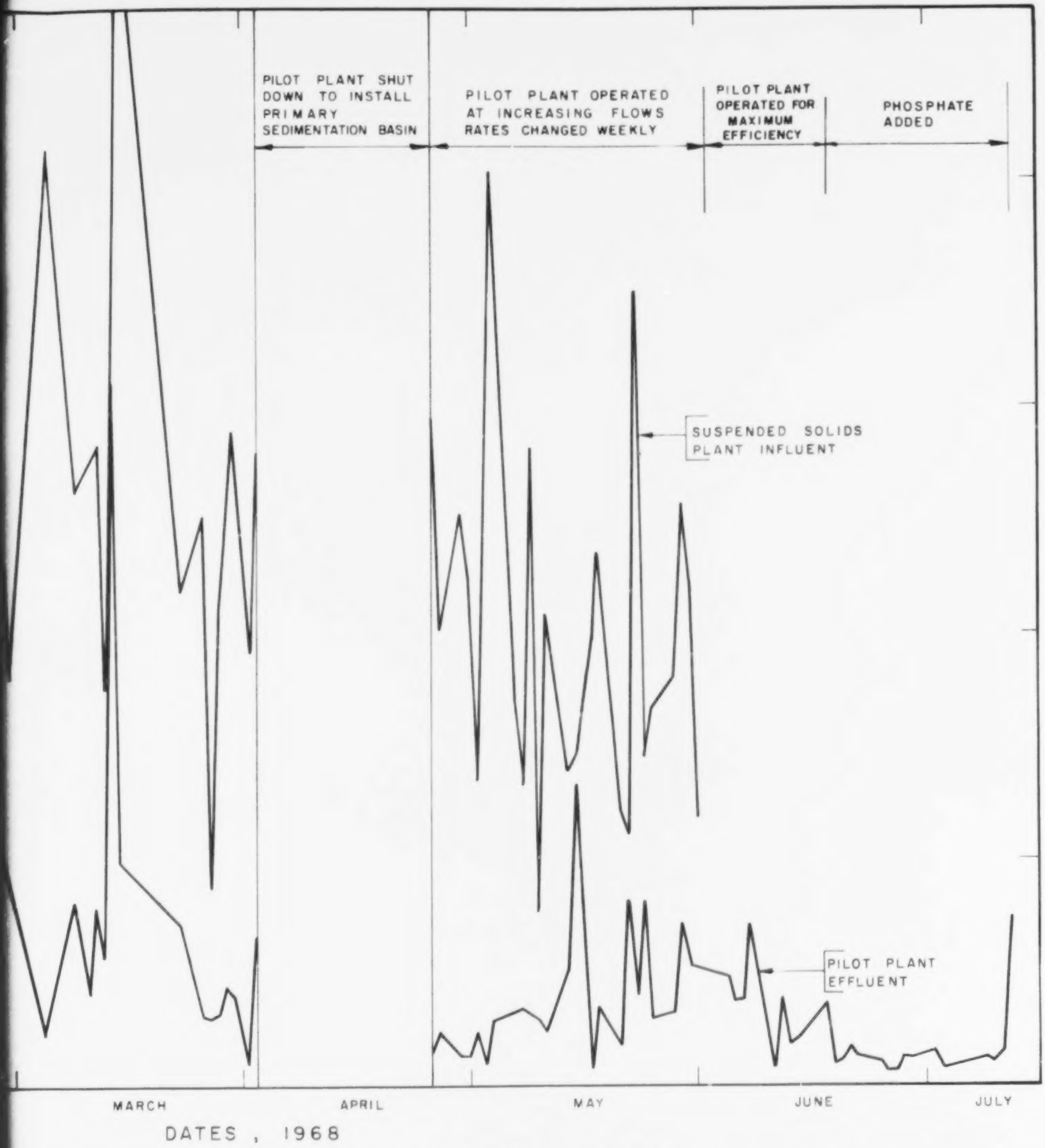


FIG. 13 CHRONOLOGICAL RECORD OF SUSPENDED SOLIDS IN PILOT PL



ORD OF SUSPENDED SOLIDS IN PILOT PLANT INFLUENT AND EFFLUENT would have occurred in a mixture of the total tannery effluent for the sampling period. There are, therefore, inconsistencies in the data such as a negative removal of suspended solids across a sedimentation unit while at the same time an accumulation of sludge in the bottom of the unit. This can result if the wastes passing through lose some of their suspended solids in the sedimentation basin and the individual samples of the effluent from the sedimentation basin react with each other in the composite to create new suspended solids in excess of those contained in the influent to the sedimentation basin.

## Suspended Solids Removal in the Primary System

Fig. 14 is a plot of the percent removal of suspended solids versus overflow rate for the primary sedimentation basin. The results shown on Fig. 14 indicate that the suspended solids removal varied from 2 percent to 72 percent. The line on Fig. 14 is the line of best fit. The average removal of suspended solids by primary sedimentation was about 38 percent as determined by a least squares fitting of the data plotted on Fig. 14.

From this example, we may draw the conclusion that the effectiveness of the sedimentation basin cannot be truly evaluated from a study of the influent and effluent suspended solids. A similar argument may be made for the use of the total solids test for this purpose. It is our opinion that the best evaluation of the effectiveness of a sedimentation basin treating the wastewaters from the tannery is the amount of sludge accumulating on the bottom of the sedimentation basin.

Fig. 15 is a plot of the amount of sludge removed from the primary sedimentation basin as a function of overflow rate. These data furnish a fairly consistant pattern; much more so than percent solids removal.

Between the 1st and the 31st of May, 1968, the average amount of sludge removed from the primary sedimentation basin was 4,300 lbs per million gallons of waste treated. Judged on this basis, the results are equivalent to a removal of 24 percent of the suspended solids entering the sedimentation basin. For the same period, the amount of sludge removed from the carbonation basin amounted to 4,536 lbs per million gallons of waste treated. The total sludge removed by the two basins operating in series amounted to 8,836 lbs per million gallons of waste treated. This amounts to about 50 percent removal of the suspended solids entering the system.

A further complication which enters the consideration of solids removal efficiency is concerned with the removal of the excess lime which is used in the de-hairing process. The lime is employed as a dilute slurry of hydrated lime. When this dilute slurry is discharged to the sewerage system, it consists of a saturated solution of calcium hydroxide, calcium chloride, and calcium carbonate. When this mixture is added to the acid wastes from the tanning processes, the high alkalinity causes a precipitation of the chromium as chromium hydroxide. The interaction of all of these compounds together with pH changes is extremely complex and variable from

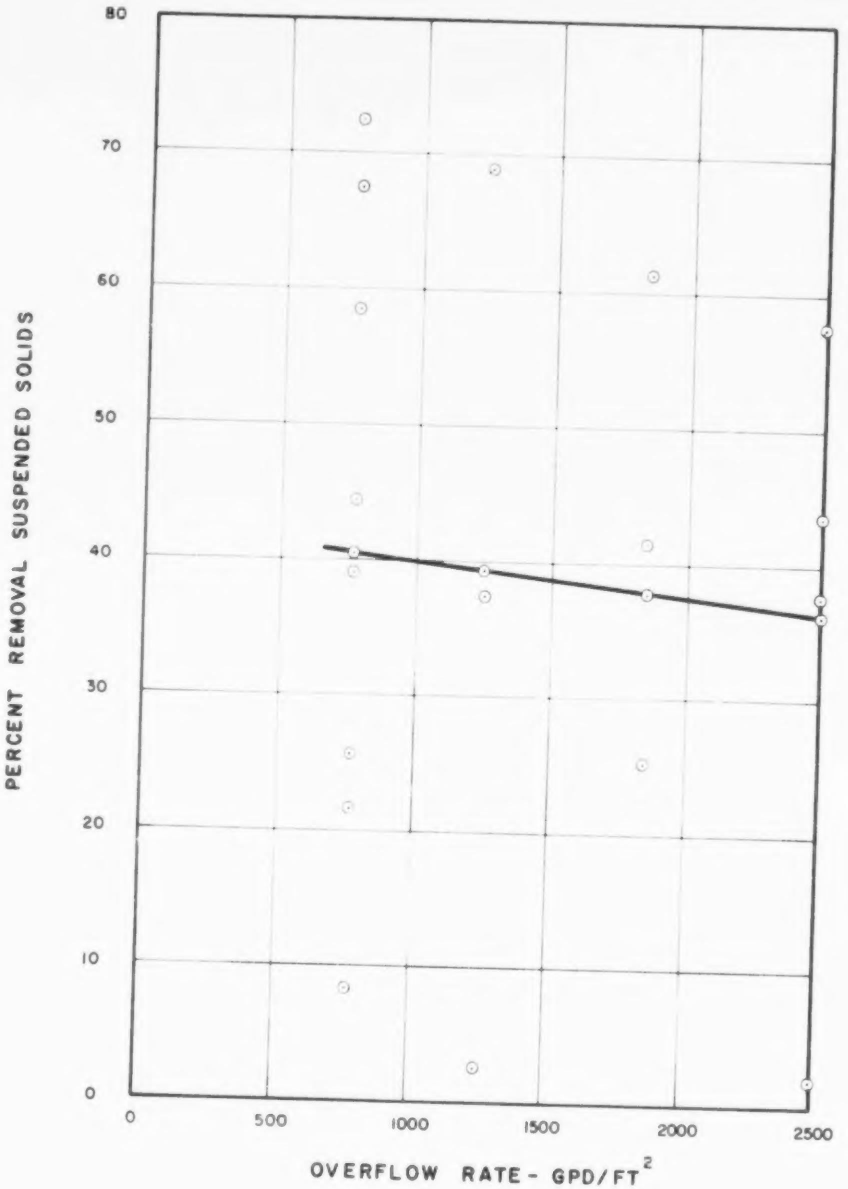


FIG. 14 SUSPENDED SOLIDS REMOVAL VS. OVERFLOW RATE-PRIMARY SEDIMENTATION BASIN

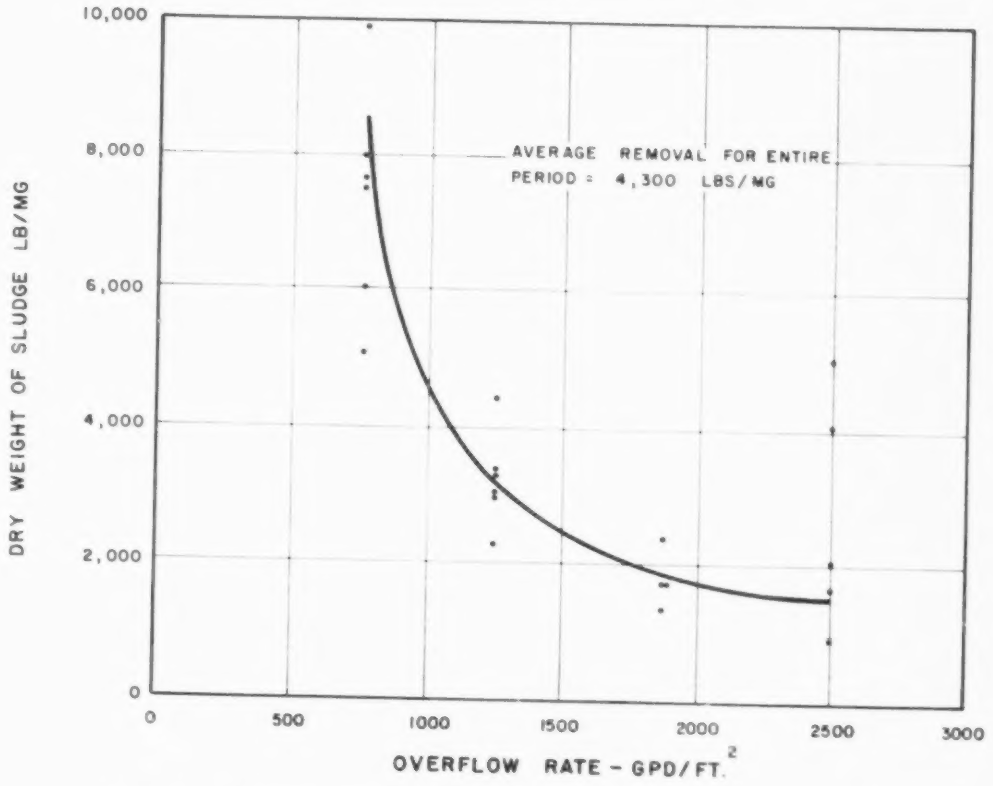


FIG. 15 WEIGHT OF SLUDGE REMOVED VS. OVERFLOW RATE, PRIMARY SEDIMENTATION BASIN

minute to minute in the waste discharges; some of the precipitates formed are colloidal in nature and do not settle readily. Other of the precipitators are flocculant in nature and tend to coagulate and settle well. However, the waste is predominantly alkaline and is higher in pH value than is desirable for biological treatment of the wastes. Carbon dioxide was selected as the most suitable acid for the reduction of the pH to a level satisfactorily for biological treatment. The advantages of using carbon dioxide for this purpose are:

1. Carbon dioxide is readily and economically available from the flue gas in the tannery power house.

2. Carbon dioxide reacts with the alkalinity in the wastes to form carbonates which create a strong buffering system. This buffering system permits a reasonable adjustment in pH to about 9.5 which is low enough to permit biological action but not low enough to permit the escape of $H_2S$ gas from the waste.

3. Calcium carbonate which is formed is a highly insoluble compound of calcium which may be removed by sedimentation.

The carbonation upflow-sedimentation basin was selected as the most suitable equipment for the introducing the flue gas into the tannery wastes and for removing the calcium carbonate. The selection of the upflow sedimentation type of basin was based upon the characteristics of calcium carbonate precipitation.

In the upflow sedimentation basin, a sludge blanket consisting of previously precipitated particles of calcium carbonate is maintained. The flow of the treated wastes, following carbonation, is upward through this blanket of particles. The particles in the blanket form nuclei on which freshly precipitated calcium carbonate may deposit. In the absence of such nuclei super-saturated solutions of calcium carbonate may be stable for considerable periods of time. It has been found in water softening operations that contact with calcium carbonate particles is essential to the removal of calcium carbonate from a saturated solution.

The carbonation basin therefore, removes both suspended and dissolved solids from the waste flow. During the initial stages of the pilot plant operation, the carbonation-upflow sedimentation basin acted both as a primary sedimentation basin and as a carbonation basin. The amount of sludge which precipitated and settled in this basin was in excess of the sludge handling capacity of the basin and the basin failed to operate in a satisfactory manner. Excess amounts of suspended solids were carried out of the basin by the effluent flow. Furthermore, rapid fluctuations in the quality of the incoming wastes, rendered the proper operation of the carbonation process almost impossible. In order to solve these difficulties, a primary sedimentation basin was installed ahead of the carbonation sedimentation basin. The primary sedimentation basin removed about 25 percent of the suspended solids. These solids contained a large percentage of lime, particularly during periods when the suspended solids concentration was heavy. The detention period in the primary sedimentation basin was about two hours and some mixing occurred in this basin. As a result of this mixing and the removal of the heavier suspended solids, the quality of the inflow to the carbonation basin became considerably more uniform. The more uniform quality permitted a better control of the carbonation process since changes in quality and the necessity for adjustment of the rate of carbonation were not rapid. The removal of solids by the carbonation basin was quite irregular. Hence again, the results must be judged on the amount of solids actually removed. The operating results for the carbonation basin are shown on Fig. 16.

On Fig. 16, the upper line represents the results obtained from the carbonation upflow sedimentation basin at the time that this basin was being utilized both for primary sedimentation and carbonation. After the primary sedimentation basin had been installed, the flow of solids to the carbonation upflow basin was substantially reduced and therefore the amount of material to be removed was reduced and the amount of sludge which accumulated in the basin was less. For an overflow rate of 1,000 gpd/ft the removal of sludge removed was about 16,000 lbs per million gallons before the primary basin was installed. After the primary basin was installed, the removal was about 2,500 lbs of sludge per million gallons of waste treated.

Prior to the installation of the primary sedimentation basin, the total solids flow from the carbonation basin into the activated sludge unit averaged about 6,000 mg/l. After the primary sedimentation basin was installed, the average concentration of total solids in the carbonation basin effluent to the activated sludge basin was about 5,170 mg/l. In general, sanitary sewage containing about 500 mg/l of total solids comprised about 1/3 of the influent flow to the activated sludge unit. From the above figures, it may be computed that the average total solids concentration in the influent to the activated sludge unit was about 3,610 mg/l. The effluent from the secondary sedimentation basin averaged about 2,200 mg/l for total solids. Hence, it may be seen that the activated sludge unit, including secondary sedimentation, removed about 1,410 mg/l of total solids, or about 39 percent of the influent solids.

## Removal of Calcium

The tannery at South Paris uses between 7,000 and 8,000 lbs of hydrated lime per day. Most of the lime is used in the de-hairing process. As the de-hairing process is completed, the spent lime solutions are discharged to the sewerage system. In addition to the lime used, the tannery also uses about 300 lbs of calcium chloride each day which is also discharged to the sewerage system. During the waste survey in April,

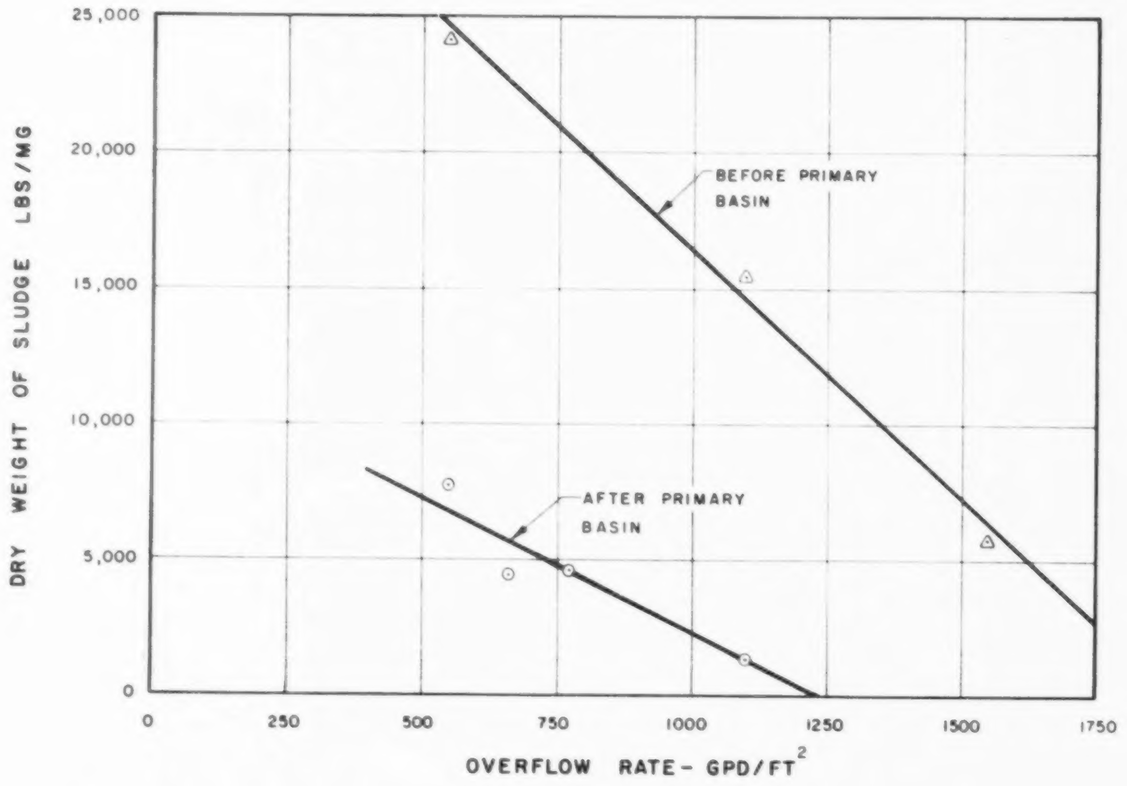


FIG. 16 WEIGHT OF SLUDGE REMOVED VS. OVERFLOW RATE, CARBONATION - UPFLOW - SEDIMENTATION BASIN

1968, the analyses of the waste samples indicated a discharge of 8,275 lbs per day of calcium expressed as calcium carbonate. The equivalent hydrated lime, having a purity of 93 percent, would be about 6,600 lbs per day giving a reasonably good check against the amount of lime used in the tannery. The average concentration of calcium in the waste samples was 1,065 mg/l expressed as calcium carbonate.

Calcium and magnesium are the two principal elements which contribute to the hardness of a water supply. It is therefore, advisable to remove as much as possible of these compounds from any waste prior to discharge from an industrial operation. The most satisfactory way of removing large amounts of calcium from water solution is by converting it into an insoluable compound which may be removed by sedimentation. The solubility of some of the calcium compounds which might occur in tannery wastes are listed below:

Calcium carbonate - 14 mg/l
Calcium sulphate - 2,000 mg/l
Calcium hydroxide - 1,600 mg/l

The solubilities listed above are solubilities of the compounds in distilled water. The actual solubility of each of these compounds depends greatly upon the pH, the total solids content, and the total concentration of various common ions. However, as may be seen from the above table, calcium carbonate has the lowest solubility and offers the best opportunity for the removal of calcium from the waste. In order to convert the calcium present in the waste solution to calcium carbonate it is necessary to supply a sufficient amount of carbonate ion to react with the calcium present. The most economical source of the carbonate ion was found to be carbon dioxide in the flue gas from the power plant at the tannery. This was not the only reason for using flue gas but is one of several reasons. Analyses of the flue gas indicated that it contained about 11 percent carbon dioxide.

Flue gas was taken directly from the stack at the power house and pumped with a gas compressor to the pilot plant. At the pilot plant, the flow of gas was measured with an orifice meter and diffused into the waste flow in the manner previously described.

The resulting removal of calcium by the plant may be divided into three parts: the removal in the primary sedimentation basin, the removal in the carbonation upflow sedimentation basin, and the removal by the activated sludge process. The results for the removal of calcium are presented in Table 8.

Table 8 lists the removal of calcium into two phases. The first phase covers the period before the primary sedimentation basin was installed, during which time the upflow carbonation-sedimentation basin served as both primary sedimentation and carbonation basin. The second phase covers the period after the primary sedimentation basin was installed. It may be seen from Table 8 that during the first phase, the average influent concentration of calcium was 1,300 mg/l. Following carbonation

## TABLE 8. REMOVAL OF CALCIUM IN THE PILOT PLANT

| | Analyses for Calcium (as Ca $CO_3$) mg/l | | | |
|---|---|---|---|---|
| Date | Plant Influent | Primary Basin Effluent | Carbonation Basin Effluent | Plant Effluent |
| Mar. 22, 1968 | 595 | | 435 | 222 |
| 25 | 742 | | 793 | 198 |
| 26 | 1,030 | | 836 | |
| 27 | 1,170 | | 1,230 | 395 |
| 28 | 880 | | 540 | 410 |
| 29 | 1,890 | | 1,110 | 518 |
| April 1 | 1,090 | | 748 | 202 |
| 2-3 | 2,050 | | 610 | 195 |
| | | PRIMARY BASIN INSTALLED | | |
| 24 | 1,350 | | 620 | 260 |
| 25 | 1,310 | | 590 | 270 |
| 26 | 1,380 | | 560 | 250 |
| 29 | 1,740 | | 630 | 168 |
| 30 | 1,680 | | 670 | 260 |
| May 2 | 2,000 | 993 | 566 | 351 |
| 3 | 2,230 | 1,070 | 764 | 360 |
| 6 | 1,180 | 974 | 606 | 291 |
| 7 | 1,190 | 818 | 533 | 469 |
| 8 | 881 | 1,040 | 727 | 408 |
| 9 | 388 | 360 | 505 | 428 |
| 10 | 978 | 937 | 719 | 436 |
| 13 | 998 | 816 | 525 | 307 |
| 14 | 840 | 929 | 622 | 501 |
| 16 | 776 | 1,010 | 727 | 493 |
| 17 | 2,300 | 1,450 | 848 | 465 |
| 20 | 950 | 1,180 | 1,000 | 295 |
| 21 | 770 | 1,100 | 608 | 445 |
| 22 | 1,150 | 1,160 | 1,060 | 545 |
| 23 | 1,140 | 1,140 | - | 602 |
| 24 | 552 | 800 | 676 | 466 |
| 27 | 1,160 | 917 | 606 | 311 |
| 28 | 792 | 929 | 660 | 350 |
| 29 | 723 | 769 | 598 | 451 |
| 31 | 684 | 1,030 | 505 | 295 |
| Averages | | | | |
| Before Primary | 1,300 | - | 721 | 280 |
| After Primary | 1,085 | 973 | 677 | 413 |
| Percent Removals | | | | |
| Before Primary | | | 45 | 78 |
| After Primary | | 10 | 38 | 62 |

and upflow settling, the average concentration was 721 mg/l, representing a removal of about 45 percent by carbonation and sedimentation. During this time, the effluent concentration from the sedcondary sedimentation basin averaged 280 mg/l of calcium, as calcium carbonate, representing an overall removal for the pilot plant of about 78 percent. Following the installation of the primary sedimentation basin, the average influent calcium concentration was 1,085 mg/l. The effluent from the primary sedimentation basin contained on the average a concentration of 973 mg/l of calcium representing a 10 percent removal in the primary sedimentation basin. For the same interval of time, the effluent from the carbonation upflow sedimentation basin was 677 mg/l of calcium, representing an average removal across the primary and the carbonation basin of about 38 percent of the influent calcium. The average concentration of calcium in the final plant effluent during this time was found to be 413 mg/l, representing a removal of about 62 percent of the calcium across the pilot plant. The difference between the 78 percent removal of calcium prior to the primary sedimentation basin and the 62 percent subsequently are not considered to be statistically significant.

Definite explanation cannot be offered for the fact that the overall removal of calcium prior to the installation of the primary tank, was higher than the removal following the installation of the primary sedimentation basin. The concentration of calcium in the effluent from the carbonation upflow sedimentation basin was lower following the installation of the primary sedimentation basin. However, the removal in the activated sludge unit was considerably lower during this time. One possible explanation might be found in the rate of operation in the secondary treatment system. Prior to May 10, the secondary system was operated at a rate of about 5 gpm whereas, starting on May 13th, the rate was gradually increased until on the 27th, 28th, and 29th, the rate of operation was 9.5 gpm. However, the removal of between 78 and 62 percent of the calcium across the plant as a whole compares favorably with the results obtained during a previous pilot plant investigation in the tannery, reported in a report dated June, 1967. The cited report dealt with the treatment of only the beam house wastes. The results of treatment of the beam house wastes indicated a 63 percent removal of calcium across the plant.

Inasmuch as the design flow for the Little Androscoggin River to which the effluent discharges, is about 5.4 mgd, the addition of 1.0 mgd of flow containing about 400 mg/l of calcium carbonate will increase the hardness of the water by about 63 mg/l. The resulting hardness is well within the U.S. Public Health Standards for drinking water, and therefore should be acceptable to meet the water quality standards of the Little Androscoggin River.

## Removal of Sulfides

Between May 6, 1968, and June 21, 1968, a number of analyses of the sulfide concentrations at various points throughout the pilot plant were made. The results of these analyses are presented in Table 9. From Table 9, it may be seen that the average sulfide concentration in the pilot plant in-

## TABLE 9. REMOVAL OF SULFIDES IN THE PILOT PLANT

| Date | | Sulfide Analyses of Composite (as $S^{=}$), mg/l | | |
|---|---|---|---|---|
| | Plant Influent | Primary Basin Effluent | Carbonation Basin Effluent | Plant Effluent |
| May 6 | 68 | 78 | 69 | 0.4 |
| 8 | 109 | 88 | 57 | 0.9 |
| 14 | 90 | 82 | 70 | 6.0 |
| 16 | 107 | 79 | 69 | 0.2 |
| 21 | 47 | 73 | 66 | 1.4 |
| 23 | 130 | 70 | 112 | 4.0 |
| 27 | 77 | 134 | 98 | 2.2 |
| 29 | 80 | 85 | 41 | 1.3 |
| June 17 | 64 | 100 | 52 | 0 |
| 18 | 49 | 61 | 45 | 0 |
| 19 | 46 | 46 | 33 | 0.2 |
| 20 | 70 | 52 | 55 | 0 |
| 21 | 39 | 39 | 28 | 3.0 |
| Averages | 75 | 76 | 61 | 0.76 |
| Percent removal | | 0 | 19 | 99.0 |

fluent during this period was about 75 mg/l. This concentration was somewhat higher than the concentration found during the April survey in the total tannery discharge (53 mg/l). However, as may be seen from Table 9, the sulfide concentration varied considerably from day to day ranging from a low of 39 mg/l to a maximum of 109 mg/l.

The results of these analyses show that the average concentration of sulfide in the effluent from the primary sedimentation basin was 76 mg/l representing no removal of sulfide from the waste in passage through the primary sedimentation basin. The average concentration of sulfide in the wastes discharged from the carbonation basin was 61 mg/l, which represents a removal of 19 percent in passage through the carbonation-sedimentation basin. These results show that if the pH of the solution which contains the sulfides is maintained above about 9, very little of the sulfide is lost from the solution. Laboratory tests described later showed the same results. The loss in the carbonation-sedimentation basin may be due at least in part to removal of protein solids and hair debris to which sodium sulfide is chemically or physically attached.

The right-hand column in Table 9 records the results of sulfide analyses made on the pilot plant effluent for the same period of time. These results indicate that the sulfide content in the wastes after treatment ranged from a low of 0 to a maximum of 6 mg/l. The average concentration of sulfide in the discharge was 0.76 mg/l which represents 99.0 percent removal of sulfide from the wastes being treated.

As will be shown later under the section of this report entitled "Special Tests," the mechanism by which the sulfide was removed is definitely a biological process, in which the sulfides are oxidized to sulfate.

### Removal of Chromium

Chrome tanning is essentially the reaction of the chromic (CR+3) ion or its complex with the proteins in the hide substance. There is no hexavalent chromium present in the wastewaters from the tannery. All dichromate used in the tannery is reduced to the trivalent state before being used in the processes. When chrome tanning is completed, the leather is washed free of excess chromium solution then neutralized with a mild alkali. The 48-hour waste survey conducted in April, 1968, showed that the average concentration of chromium in the wastes from the tannery was about 236 mg/l. However, inasmuch as the tanning wheels were dumped at irregular intervals, the chromium found in 2-hour composites of the wastes varied from about 30 mg/l to about 570 mg/l.

In order to obtain acid waste containing chromium for use in the pilot plant it was necessary to catch the flow in the sewer when a tanning or color wheel was dumped. The sample caught would sometimes have a high chromium concentration and sometimes a low concentration. The only immediate basis for judging the strength of the sample was the acidity of the sample. The acidity was not a good basis for judging the chromium content. Analyses of composites showed that the chromium concentration of the wastes entering the pilot plant varied from less than 1 mg/l to more than 85 mg/l.

The results of the removal of chromium by the pilot plant are presented in Table 10. The results in Table 10 are divided into two parts. One part represents the results obtained before the primary basin was installed, the other part after the primary basin was installed. In the testing period before the primary basin was installed, the average concentration of chromium in the plant influent was about 71 mg/l. During this period, the influent went directly into the carbonation basin. The effluent from the carbonation basin had an average chromium content of 21 mg/l, representing a removal of about 71 percent in the carbonation-sedimentation basin. The effluent from the pilot plant following activated sludge treatment and secondary sedimentation, had an average chromium content of 4.7 mg/l, representing a 93 percent removal of chromium across the pilot plant. After the primary sedimentation basin was installed, the average chromium content of the pilot plant influent was 29.8 mg/l. Following primary sedimentation, the average chromium content was 20.0 mg/l representing a 33 percent removal of chromium by primary sedimentation. The effluent from the carbonation-upflow sedimentation basin had an average chromium content of 15.2 mg/l following installation of primary sedimentation. This represented a 49 percent removal of chromium by sedimentation in the primary sedimentation basin and the carbonation upflow sedimentation basin operating in series. During this same time, the plant effluent had an average chromium content of 3.6 mg/l representing an 88 percent removal of chromium across the pilot plant as a whole.

In order to determine the affects of high concentrations of chromium on the activated sludge process, samples of chromium solution used in the tanning process were added continuously to the activated sludge unit for 4 days starting on July 9, 1968, and extending through July 12, 1968. On the first day, 40 mg/l of chromium was added to the influent to the aeration basin. On the second day, 80 mg/l of chromium was added to the influent. On July 11, the third day, 120 mg/l of chromium was added to the influent, and on July 12, the fourth day, 160 mg/l of chromium was added to the aeration basin influent. The chromium content of the mixed liquor in the activated sludge basin was analyzed, the chromium in the return sludge or waste sludge was analyzed, and the chromium in the pilot plant effluent was analyzed. The results of these tests are shown in Table 11. From Table 11, it may be seen that the chromium content in the mixed liquor on the first day was about 70 mg/l. The chromium in the waste sludge or the return sludge was 122 mg/l, while the chromium in the pilot plant effluent was 1.5 mg/l. On the second day when 80 mg/l of chromium was being added to the influent to the activated sludge unit the chromium content of the mixed liquor was found to be 115 mg/l and the pilot plant effluent has a chromium content of 4.3 mg/l.

## TABLE 10. REMOVAL OF CHROMIUM IN PILOT PLANT

| Date | Chromium Analyses (as Cr), mg/l Plant Influent | Primary Basin Effluent | Carbonation Basin Effluent | Plant Effluent |
|---|---|---|---|---|
| March 29, 1968 | 80.1 | | 34 | 6.4 |
| April 1 | 48.1 | | 23 | 2.8 |
| 2-3 | 84.4 | | 12 | 5.0 |
| | | Primary Basin Installed | | |
| May 6 | 9.7 | 4.3 | 3.2 | 2.2 |
| 8 | 47.9 | 26.6 | 22.2 | 1.9 |
| 16 | 36.5 | 12.5 | 12.5 | 0.5 |
| 21 | 33.0 | 22.6 | 22.6 | 3.0 |
| 23 | 11.6 | 12.6 | 7.8 | 2.8 |
| 27 | 16.0 | 12.6 | 6.1 | 1.5 |
| 29 | 34.3 | 13.2 | 5.0 | 19.0 |
| June 17 | 52.5 | 34.0 | 21.8 | 2.1 |
| 18 | 32.3 | 28.4 | 21.4 | 1.6 |
| 19 | 37.1 | 37.3 | 26.8 | 2.0 |
| 20 | 22.3 | 21.3 | 19.4 | 2.8 |
| 21 | 24.8 | 14.6 | 13.6 | 3.2 |
| Average before Primary | 70.9 | - | 21 | 4.7 |
| Percent Removal | | - | 71 | 73 |
| Average after Primary | 29.8 | 20.0 | 15.2 | 3.6 |
| Percent Removal | | 33 | 49 | 88 |

The test results for chromium analyses for July 11 and 12 cannot be located. However, it can be reported that the pilot plant continued to function with no noticeable decrease in the removal of BOD and suspended solids as a result of the high chromium content in the mixed liquor.

As may be seen from Table 11, the chromium content of the activated sludge unit apparently was concentrated in the sludge itself and was removed via the waste sludge. The chromium content of the secondary sedimentation basin effluent showed no significant increase in chromium due to the high feed of chromium directly to the activated sludge unit.

It is apparent from the results of the chromium studies, as reported in Tables 10 and 11, that chromium is removed during all phases of the proposed treatment system. In passing through the primary sedimentation basin and the carbonation-upflow-sedimentation basin, the chromium content of the wastes were reduced to about 20 mg/l, more or less independently of the influent concentration of chromium. In passing through the activated sludge process, the chromium content of the wastes was further reduced to about 0.5 to 3.2 mg/l. The special tests showed that even when the chromium content of the activated sludge unit is increased beyond that which would reasonably be expected, the concentration of chromium found in the effluent will still be about 4 mg/l. It is, therefore, our opinion that a full scale waste treatment plant operating on the same processes tested in the pilot plant will reduce the chromium content of the tannery effluent to about 4 mg/l.

## Sludge Handling

Sludges constitute the solids which are removed from the waste by the treatment processes. In the proposed tannery waste treatment, sludges will be removed from the process at three locations: the underflow from the primary sedimentation basin, the underflow from the carbonation upflow-sedimentation basin, and the excess underflow from the secondary sedimentation basin. The last named sludge is known as excess sludge. Table 12 lists the weight and volume of the sludges removed from the various operations during the pilot plant testing. Table 12 is divided into two parts; the first part listing the sludges obtained before the installation of the primary sedimentation basin, and part two lists the sludges obtained subsequent to the installation of the primary sedimentation basin.

From Table 12 it may be seen that the total amount of sludge obtained in the pilot plant varied from about 14,000 lbs of dry solids per million gallons of waste treated to about 11,000 lbs per million gallons of waste treated. The volumes of the sludge varied from about 38,000 gallons per million gallons of waste treated to about 29,000 gallons per million gallons of waste treated. The volumes of the sludge, therefore, appeared to be about 3.7 percent of the waste treated. The average solids concentration in the sludges is about 4.5 percent. The range of concentrations of total solids in the sludge was from 1 percent for the secondary sludge to about 8.2 percent for the sludge removed from the carbonation basin following the installation of the primary sedimentation basin. It is recommended

## TABLE 11. RESULTS OF HIGH CHROMIUM CONCENTRATION ON ACTIVATED SLUDGE

| Date 1968 | | Chromium added, mg/l | Chromium in mixed liquor, mg/l | Chromium in mixed sludge, mg/l | Chromium in pilot plant effluent, mg/l |
|---|---|---|---|---|---|
| July | 9 | 40 | 69.4 | 222 | 1.5 |
| | 10 | 80 | 115.0 | 378 | 4.3 |
| | 11 | 120 | | | |
| | 12 | 160 | | | |

| Date 1968 | | Chromium added, mg/l | Carbonation Basin Effluent BOD, mg/l | Pilot Plant Effluent BOD, mg/l |
|---|---|---|---|---|
| July | 9 | 40 | 1,380 | 50 |
| | 10 | 80 | 755 | 54 |
| | 11 | 120 | 855 | 50 |
| | 12 | 160 | | |
| Averages | | | 997 | 51 |
| Percent removal | | | | 95 |

## TABLE 12. WEIGHT AND VOLUME OF SLUDGES AS DRAWN

| Source | Dry Weight lbs/mg | Volume gals/mg | Percent Solids |
|---|---|---|---|
| Carbonation basin before primary installed | 13,400 | 32,500 | 5 |
| Secondary excess sludge before primary | 434 | 5,400 | 1 |
| Total sludge before primary was installed | 13,834 | 37,900 | 4.2 |
| Primary sedimentation basin sludge | 4,300 | 7,380 | 7 |
| Carbonation basin after primary installed | 4,536 | 6,630 | 8.2 |
| Secondary excess sludge after primary | 1,877 | 14,500 | 1.5 |
| Total sludge after primary was installed | 10,713 | 28,510 | 4.5 |

that the sludge dewatering facilities be designed to handle at least 40,000 gallons of sludge per million gallons of waste treated. The weight of sludge for which the sludge handling facilities should be designed is about 15,000 lbs per million gallons of waste treated.

Table 13 presents the average composition of the sludges obtained during the pilot plant operation. From Table 13, it may be seen that the primary sludge contained,on the average, 7 percent total solids of which 46.6 percent were volatile. Based upon the dry weight of the solids in the primary sludge, the solids contained 1.25 percent chromium, 18 percent calcium, 0.19 percent sulfide, 0.12 percent total phosphate, as phosphorous and 0.094 percent polyphosphate, as phosphorous. The carbonation basin sludge after the primary sedimentation basin was installed, contained 8.2 percent solids of which 34 percent were volatile. The solids contained 0.56 percent chromium, 39.6 percent calcium, 0.2 percent sulfide, 0.11 percent total phosphate and 0.055 percent polyphosphate. The sludge from the secondary sedimentation basin contained on the average, 1.56 percent total solids of which 64.8 percent were volatile. The solids in the secondary sedimentation basin sludge contained 1.3 percent chromium, 14.14 percent calcium, 0.55 percent sulfide, 0.18 percent phosphate and 0.13 percent polyphosphate. These results indicate that the solids from the primary sedimentation basin and the carbonation-upflow-sedimentation basin contained a high percentage of mineral matter (indicated by the relatively low percentage of volatile solids) whereas the secondary sedimentation basin sludge contained a much higher percentage of organic matter, as indicated by the relatively high volatile solids content.

It is of interest to note that all of the sludges contained a relatively high concentration of chromium, i.e. between 0.6 and 1.3 percent. On the other hand, the sulfide concentration in the sludges was relatively low, about 0.2 percent in the primary sludges. The average sulfide concentration for the secondary sludge was 0.55 percent. This high average resulted from including one unusually high value.

## Sludge Dewatering

Tests were made on dewatering the sludge by the use of a solid bowl centrifuge. The centrifuge used was a production model, 6-in diameter solid bowl type. The liquid capacity of the centrifuge was about 2 gpm. A series of preliminary runs were made by pumping sludge from the various treatment units, i.e., the primary sedimentation basin, the carbonation-upflow-sedimentation basin, and the secondary sedimentation basin. The preliminary tests showed that the sludge from the primary sedimentation basin and the carbonation-upflow sedimentation basin dewatered readily to yield a relatively dry cake. The excess activated sludge from the secondary sedimentation basin dewatered very poorly and gave a semi-fluid sludge having a high water content. On the basis of the preliminary tests, the excess activated sludge from the secondary sedimentation basin was mixed with primary sludge before the quantitative dewatering tests were made.

TABLE 13. AVERAGE COMPOSITION OF TANNERY PILOT PLANT SLUDGE

| Components | Primary Sludge | Carbonation Sludge<br>Before Primary Installed | <br>After Primary Installed | Secondary Sludge<br>Before Primary Installed | <br>After Primary Installed |
|---|---|---|---|---|---|
| Total solids, percent | 7.0 | 5.0 | 8.2 | 0.965 | 1.56 |
| Volatile solids, percent | 46.6 | 39.1 | 34.0 | 61.3 | 64.8 |
| Chromium, percent dry weight | 1.25 |  | 0.56 | 1.00 | 1.30 |
| Calcium, percent dry weight | 18.0 |  | 39.6 |  | 14.14 |
| Sulfide, percent dry weight | 0.19 |  | 0.20 |  | 0.55 |
| Total phosphate, percent dry weight | 0.122 |  | 0.112 |  | 0.18 |
| Polyphosphate, percent dry weight | 0.094 |  | 0.055 |  | 0.13 |

Table 14 presents the results of dewatering the sludge without the use of coagulant chemicals. In the series of tests reported in Table 14, the centrifuge was operated at three different speeds i.e., 3,000 rpm, 4,000 rpm, and 5,000 rpm. These speeds of rotation resulted in centrifugal forces of 750 times gravity, 1,330 times gravity, and 2,080 times gravity respectively. The mixture of primary and secondary sludge had an initial concentrations ranging from 4.16 percent to 5.78 percent. The total solids in the dewatered sludge discharged from the centrifuge ranged from 19.84 percent to 21.25 percent. The liquid effluent discharged by the centrifuge contained suspended solids ranging from 1.68 percent to 2.49 percent. The recovery of suspended solids from the sludge ranged from 55 to 60 percent. The dry cake was similar in nature to manure and could be trucked to a disposal area.

The carbonation sludge tested ranged in suspended solids concentration from 2.42 percent to 2.91 percent. The resulting dewatered sludge ranged from 29.5 percent solids to 33.7 percent. The suspended solids in the liquid effluent from the centrifuge ranged from 0.42 percent to 0.46 percent. The recovery of suspended solids ranged from 75 percent to 86 percent. The sludge cake was quite dry and was easily transportable by ordinary dump trucks.

The speed of rotation of the centrifuge apparently had little influence upon the dewatering of the sludge tested. The tests showed a very slight increase in the total solids content of the sludges discharged as the speed of rotation increased. The increase in solids amounted to about 1.4 percent for the primary secondary sludge mixture when the speed of rotation was increased from 3,000 to 5,000 rpm. For the carbonation sludge the resulting increase in solids was about 4.1 percent when the speed of rotation was increased from 3,000 to 5,000 rpm. On the other hand, the highest recovery of suspended solids was achieved at a speed of rotation of 4,000 rpm.

A second series of tests for dewatering the sludge was carried out using a synthetic polymer. This material was used in accordance with the directions of the manufacturer. It was applied to the sludge at concentrations of 1 lb per ton of solids in the sludge, 2 lbs per ton and 4 lbs per ton. The centrifuge was operated at 4,000 rpm which yielded a centrifugal force of 1,330 times gravity. The results of these tests are reported in Table 15. The suspended solids in the primary secondary sludge mixture ranged from 4.98 percent to 5.89 percent. The total solids in the dewatered sludge ranged from 21.1 percent to about 20 percent. The recovery of suspended solids ranged from 42 to 53 percent. All in all, the results showed that the coagulant had little, if any, effect upon the dewatering of the primary secondary sludge mixture.

The same tests were repeated using the carbonation basin sludge and the same concentrations of coagulant. In this test, the suspended solids in the carbonation basin sludge ranged from 2.68 percent to 2.88 percent.

## TABLE 14. SLUDGE DEWATERING BY CENTRIFUGE WITHOUT COAGULANTS

| Speed of Rotation (rpm) | Centrifugal Force x Gravity | Feed Rate (gpm) | Influent Suspended Solids (%) | Effluent Suspended Solids (%) | Total Sludge Solids (%) | Removal of Suspended Solids (%) |
|---|---|---|---|---|---|---|
| PRIMARY AND SECONDARY SLUDGE MIXTURE | | | | | | |
| 3,000 | 750 | 1.94 | 4.46 | 2.01 | 19.84 | 55 |
| 4,000 | 1,330 | 1.89 | 4.16 | 1.68 | 20.07 | 60 |
| 5,000 | 2,080 | 1.67 | 5.78 | 2.49 | 21.25 | 57 |
| CARBONATION SLUDGE | | | | | | |
| 3,000 | 750 | 1.84 | 2.42 | 0.61 | 29.53 | 75 |
| 4,000 | 1,330 | 1.86 | 2.91 | 0.42 | 32.28 | 86 |
| 5,000 | 2,080 | 1.88 | 2.53 | 0.47 | 33.69 | 81 |

## TABLE 15. SLUDGE DEWATERING BY CENTRIFUGE, USING RETEN 210 COAGULANT

(Speed of Rotation 4,000 rpm, Centrifugal Force 1,330 x Gravity)

| Coagulant Concentration (lbs/ton of Solids) | Feed Rate (gpm) | Influent Suspended Solids (%) | Effluent Suspended Solids (%) | Sludge Solids (%) | Removal of Suspended Solids (%) |
|---|---|---|---|---|---|
| PRIMARY AND SECONDARY SLUDGE MIXTURE | | | | | |
| 1.0 | 1.68 | 5.67 | 3.30 | 21.07 | 42 |
| 2.0 | 1.68 | 5.89 | 3.00 | 19.94 | 49 |
| 4.0 | 1.48 | 4.98 | 2.33 | 21.13 | 53 |
| CARBONATION BASIN SLUDGE | | | | | |
| 1.0 | 1.77 | 2.73 | 0.36 | 40.96 | 87 |
| 2.0 | 1.76 | 2.68 | 0.28 | 37.26 | 90 |
| 4.0 | 1.71 | 2.88 | 0.19 | 37.76 | 93 |

The solids in the cake ranged from 87 percent to 93 percent. The application of the coagulant to the carbonation basin sludge appeared to increase the removal of suspended solids by between 5 to 10 percent. The resulting dewatered cake was also improved in that its moisture content was about 5 to 10 percent less than a comparable cake without the coagulant.

The results of the centrifuge dewatering tests indicate that the mixture of primary sludge and secondary sludge is readily dewatered by centrifugal forces ranging from 2,080 to 750 times gravity. Under satisfactory concentration for disposal by burial. The carbonation basin sludge is readily dewaterable to a concentration suitable for disposal by burial.

The use of a coagulant does not appear to increase the dewatering characteristics of the primary secondary sludge mixture to any appreciable degree, furthermore, it does not appear that the carbonation basin sludge requires the use of any coagulant aid, although the use of the coagulant does appear to increase the dryness of the cake and the percent recovery of suspended solids when used with carbonation basin sludge.

Further tests with coagulants appears to be warranted.

# SULFIDE OXIDATION

## General

In the unhairing process, sodium sulfide ($Na_2S$) and sodium sulfhydrate ($NaSH.2H_2O$) are used as part of the depilatory mixture. As a result, there is a significant amount of sulfide in the plant effluent. The ionic form of sulfide in solution is a function of the hydrogen ion concentration (pH) in accordance with the following equilibrium expressions:

$$H_2S \rightleftharpoons H^+ + HS^- \qquad (1)$$

$$HS^- \rightleftharpoons H^+ + S^= \qquad (2)$$

$$\frac{[H^+ \quad HS^-]}{[H_2S]} = K_1 \qquad (3)$$

$$\frac{[H^+ \quad S^=]}{[HS^-]} = K_2 \qquad (4)$$

$K_1 = 9.1 \times 10^{-8}$

$K_2 = 1.3 \times 10^{-12}$

The above equilibrium expressions are summarized in the table below indicating for various pH values, the percentage of the sulfide in solution which is in the form of hydrogen sulfide.

| pH | Percent $H_2S$ |
|---|---|
| 5 | 99.3 |
| 6 | 91.6 |
| 7 | 52.4 |
| 8 | 9.9 |
| 9 | 1.09 |
| 10 | 0.11 |

Hydrogen sulfide is readily released from solution to the atmosphere as a toxic gas with an obnoxious odor. As may be seen from the above table, if the pH falls below 9, a significant proportion of the sulfide content of a solution is in the form of $H_2S$. Tests have shown that sulfide concentrations as low as 1.0 mg/l can create unpleasant odors if the pH of the solution is less than 7.0. Hence, it is essential that any proposed waste treatment reduce the sulfide concentration of the waste to less than 1.0 mg/l before it is discharged.

It was found that the pilot plant treatment did in fact reduce the sulfide concentration to minimal and acceptable values. (See pilot plant results Table 9). It was important to establish the mechanism by which this reduction in concentration was accomplished. Therefore, an investigation into the fate of the sulfide was conducted and is described below.

Sulfide is a strong reducing agent which may be oxidized by various routes to other sulfur forms. It is known, for example, that sulfides may be converted to thiosulfate during the depilation process.(11) Air oxidation of sulfide may also take place with the rate of reaction dependent upon the conditions of the system. Through aerobic bacterial action, hydrogen sulfide may be oxidized to sulfate.(12)

$$H_2S + 2O_2 \xrightarrow{\text{Bacteria}} SO_4^{=} + 2H^+$$

Each of these processes as well as the physical "sweeping out" of hydrogen sulfide by aeration was investigated as one of the possible mechanisms of sulfide removal.

Previous pilot plant studies at the South Paris tannery revealed that the major portion of the sulfide in the waste was removed by the activated sludge process. Hence, the studies to determine the fate of the sulfide were primarily limited to this process. The solutions used in making the tests in the laboratory consisted of either distilled water solutions of the sulfides used by the tannery or of activated sludge samples taken from the pilot plant to which sodium sulfide was added.

## Apparatus

A glass cylinder of abut 2-1/2 liters capacity was fitted with a three hole rubber stopper. Glass tubes were passed through the holes making air tight connections. The first tube was connected to a compressed air supply while the opposite end was connected to a diffuser stone in the bottom of the cylinder. In order to prevent plugging of the diffuser by solid material or admission of oil to the liquid, a glass wool filter was interposed in the air line between the cylinder and the air supply (see Fig. 17). The second tube was attached at one end of this tube which led below the base of the cylinder. The other end of this tube reached about half way down into the cylinder. This was used to sample the contents of the cylinder by siphoning. The third tube, which acted as a vent, led to just below the bottom of the rubber stopper inside the cylinder and was connected outside of the cylinder to a rubber tube. The end of the tube was submerged in 150 milliliters of 0.1 M zinc acetate solution.

## General Procedure

The liquid to be tested, which had been previously analyzed, was placed in the cylinder after which the cylinder was securely stoppered. Aeration was then begun by passing air into the cylinder through the diffuser. Exhaust air was bubbled through a zinc acetate solution. Any hydrogen sulfide evolved reacted with the zinc acetate to form zinc sulfide. At intervals the pinch clamp on the siphon tube was opened and a portion of the liquid under aeration was siphoned off for analysis. At the end of the aeration period a portion of the liquid was also collected for analysis. The zinc acetate solution was analyzed for sulfide.

## Analytical Procedures

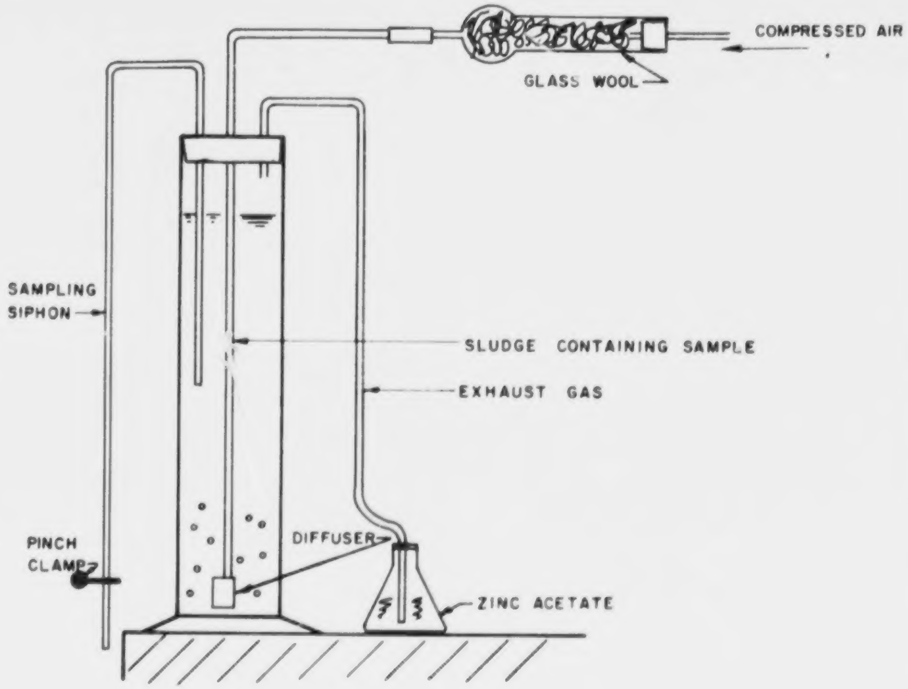
Sample Pretreatment - The sample of activated sludge mixed liquor to be analyzed was filtered through glass wool, after which the residue and glass wool were washed with distilled water. The filtrate and washings were combined and diluted to 500 milliliters in the volumetric flask for sulfide, sulfate and iodine demand analyses.

Sulfide - An aliquot of the combined filtrate and washings was placed in a 500 milliliter erlenmeyer flask. The flask was fitted with a rubber stopper through which was passed an outlet tube and a fritted glass inlet tube. The inlet was connected to a cylinder of compressed carbon dioxide gas. Two 125 milliliter erlenmeyer flasks, connected in series, were joined with the outlet tube as shown on the diagram. (Fig. 17). One hundred milliliters of 0.1 M zinc acetate solution was placed in each of the flasks and the first 125 milliliter flask was stoppered tightly. After this, 10 milliliters of concentrated sulfuric acid were added to the sample in the 500 milliliter flask and the flask was immediately stoppered tightly. The acid converted the sulfides present to hydrogen sulfide. Carbon dioxide was bubbled through the sample mixture in the flask and swept out the hydrogen sulfide into the receiving flasks where it was converted to zinc sulfide. After having bubbled carbon dioxide through the acidified sample for an hour, the sample flask was opened and the fumes were tested for hydrogen sulfide with lead acetate test paper. If there was no further evolution of hydrogen sulfide, the carbon dioxide was shut off and the apparatus dismantled.

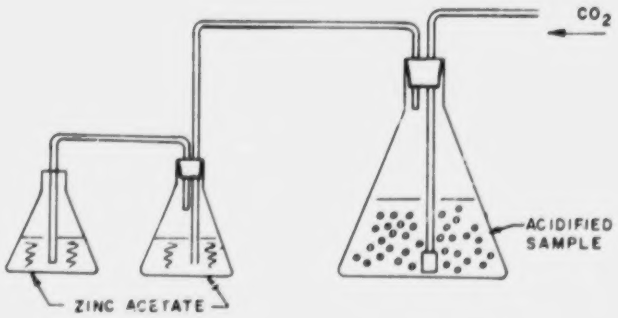
The contents of the two receiving flasks were combined. The flasks and effluent gas tubing were rinsed with water and the rinsings added to the combined zinc acetate solution. A sulfide analysis was made on the combined rinsings and zinc acetate solutions.

Hydrogen Sulfide - The zinc acetate solution containing any precipitated zinc sulfide was treated with an excess of standard iodine solution. Five milliliters of hydrochloric acid (concentrated) were added to the solution and the excess iodine was back titrated with 0.025 N phenylarsene oxide solution. The weight of the sulfide evolved was calculated from the amount of iodine consumed.

Sulfate - Another aliquot was treated with a solution of barium chloride which precipitated any sulfate or sulfite present as the insoluble barium salts. The precipitate was separated from the liquid phase of centrifuging and decanting. The precipitate was washed first with hot dilute hydrochloric acid and then with hot distilled water. This treatment removed any


COMPRESSED AIR
GLASS WOOL
SAMPLING SIPHON
SLUDGE CONTAINING SAMPLE
EXHAUST GAS
PINCH CLAMP
DIFFUSER
ZINC ACETATE

HYDROGEN SULFIDE TEST APPARATUS


$CO_2$
ACIDIFIED SAMPLE
ZINC ACETATE

TEST SET-UP FOR ANALYSIS OF SULFIDE

FIG. 17 HYDROGEN SULFIDE TEST APPARATUS

barium sulfite present and left the barium sulfate in an easily filterable condition. The barium sulfate was filtered through a weighed Gooch crucible and washed again with hot water. The barium sulfate was then dried, ignited, cooled and weighed. From the weight of Ba $SO_4$ present the amount of sulfate in the original aliquot was calculated.

Iodine Demand - An aliquot of the sample was treated with an excess of standard iodine solution, acidified, and the excess iodine was back titrated with standard phenylarseneoxide solution. The amount of iodine consumed was converted to equivalent sulfide ion by calculation as in the sulfide and H S analyses.

## Individual Tests

A series of four tests was conducted to determine the extent of sulfide removal under different conditions and to determine the fate of the sulfide under these conditions.

### Test 1

The purpose of this test was to determine the extent of oxidation of sulfide in an aqueous solution by aeration alone.

Since further tests were to establish the effect of microorganisms on the rate of sulfide oxidation, this test established a base line for the later tests.

Procedure - A stock solution of commercial sodium sulfide in water was adjusted to a pH of about 9 with hydrochloric acid. A portion of the stock solution was diluted with water and an aliquot was taken for analysis. One liter of the diluted sulfide was introduced into the test cylinder and the cylinder was stoppered tightly. Aeration was begun and continued for 2-1/2-hours. Throughout the aeration period the exhaust gas was passed through a solution of zinc acetate in order to collect any hydrogen sulfide carried out by the air flow. At various times during the aeration period samples were collected for iodine demand tests in order to roughly follow the rate of sulfide disappearance. After 2-1/2-hours, a sample of the aerated solution was collected for analysis and the aeration was stopped.

The results of the test are presented in Table 16. In Table 16 Column (1) is the time from the start of aeration until a sample was withdrawn from the solution for analysis. Column (2) is the "iodine demand" of the sample expressed as sulfide. The iodine demand is higher than the total sulfide due to the presence of iodine reducing material, in addition to the sulfide, in commercial sodium sulfide. Column (3) is the analysis of the samples for sulfide. Column (4) is the analysis of the samples for sulfate expressed as sulfide. This analysis was not made on samples in Test 1 because all sulfide lost from solution was accounted for by sulfide in the exhaust gas. Column (5) is an analysis of the sulfide contained in the exhaust gas, expressed as mg/l in the initial solution. Column (6) is a summation of the various forms of sulfide accounted for by the analyses.

## TABLE 16. TEST RESULTS - AERATION OF WATER SOLUTION OF SODIUM SULFIDE

### TEST 1

| Aeration Period (min) (1) | Iodine Demand mg/l as $S^=$ (2) | Sulfide Remaining mg/l as $S^=$ (3) | Sulfate mg/l as $S^=$ (4) | Hydrogen Sulfide Expelled mg/l as $S^=$ (5) | Total 3,4,5 mg/l as $S^=$ (6) |
|---|---|---|---|---|---|
| 0 | 120 | 82.8 | | 0 | 82.8 |
| 30 | 105 | | | | |
| 60 | 87 | | | | |
| 120 | 59 | | | | |
| 150 | 42 | 31.4 | | 51.8 | 83.2 |

Note: Sulfide solution adjusted to pH 9.0 before dilution.

The total amount of sulfide found in the exhaust gas was 51.8 mg/l (based on the initial solution). For the same period of time the sulfide content of the solution decreased by 51.4 mg/l. Hence we may conclude that the sulfide lost from the solution was "swept out" of the solution by the air and no sulfide was oxidized.

The iodine demand test which was used as a quick check on the extent of sulfide removal is not specific for sulfide. Other reducing agents were present which responded to this test. It was known from the manufacturer's analysis of the sodium sulfide that some sodium thiosulfate and sodium sulfite existed in the product as impurities. No attempt was made to determine the extent of these impurities. However, it is evident from the decrease of 79 mg/l in the iodine demand that the sulfide equivalent of about 28 mg/l of these impurities were oxidized by the aeration.

### Test 2

The preceding test showed the extent of sulfide removal from an aqueous sulfide solution by aeration alone. Test 2 was designed to show the influence of microorganisms on the sulfide removal. Since the sulfide concentration of the plant waste was reduced in the aeration tank of the pilot plant, it appeared likely that the microorganisms present in the mixed liquor had developed the capability of altering sulfide.

Procedure - Fresh activated sludge mixed liquor was collected from the pilot plant aeration tank and mixed with sodium sulfide solution. Two hundred ml of solution was prepared from the commerical sodium sulfide. The above solution was added to 1,800 ml of the fresh mixed liquor and the pH of the mixture adjusted to 9.2. Zinc acetate solution was added immediately to an aliquot of this mixture in order to fix the sulfide as insoluble zinc sulfide. Sulfate and iodine demand tests were made on the supernatant of another portion of the mixture in which the sludge had been permitted to settle.

As soon as the initial samples were collected, aeration of the remainder of the mixture was started in the cylinder as previously described in Test 1. Aeration was continued for two hours during which time two additional samples were collected for iodine demand tests. Before each of these samples and a final sample were collected, the aeration was shut off for about two minutes to allow settling of the mixed liquor solids. This was done so that the supernatant might be sampled.

Results of the test are presented in Table 17A. The concentration of sulfide sulfur was reduced by 236.7 mg/l while sulfate sulfur increased only 146.1 mg/l. The sulfide expelled during the test was only 13 mg/l, an amount insufficient to account for the difference. An analysis of the decantate from the sulfate test was made to determine if some sulfur species intermediate between sulfide and sulfate was present. This was accomplished by treating the decantate with an excess of standard iodine solution and back titrating with standard phenylarsene oxide solution. Upon converting the iodine consumed to equivalent sulfide it was found

## TABLE 17. TEST RESULTS - AERATION OF SOLUTION OF COMMERCIAL SODIUM SULFIDE IN ACTIVATED SLUDGE MIXED LIQUOR

### TEST 2

A

| Aeration Period (min) (1) | Iodine Demand mg/l as $S^=$ (2) | Sulfide mg/l as $S^=$ (3) | Sulfate mg/l as $S^=$ (4) | Hydrogen Sulfide mg/l as $S^=$ (5) | Total 2,3,4,5 mg/l as $S^=$ (6) |
|---|---|---|---|---|---|
| 0 | 209 | 238 | 84.5 | 0 | 326.4 |
| 30 | 53 | | | | |
| 60 | 29 | | | | |
| 120 | 3.6 | 2.3 | 230.6 | 13 | 250.8 |

**Note:** pH initial = 9.2 pH final = 7.45

On unfiltered portion of mixture

B

| Aeration Period (min) (1) | Iodine Demand mg/l as $S^=$ (2) | Sulfide mg/l as $S^=$ (3) | Sulfate mg/l as $S^=$ (4) | Hydrogen Sulfide mg/l as $S^=$ (5) | Total 2,3,4,5 mg/l as $S^=$ (6) |
|---|---|---|---|---|---|
| 0 | | 166 | 113.5 | | 279.5 |
| 30 | | 96 | 132 | | 228 |
| 210 | | 21 | 256.4 | | 277.4 |

**Note:** pH initial 8.0

that only a small portion of the iodine consumed could not be accounted for by the sulfide present. The unaccounted for sulfur amounted to 3.9 mg/l as sulfide in the initial sulfate decantate and 2.3 mg/l as sulfide in the final sulfate decantate. This may be a result of the presence of thiosulfate, some other reducing agent or simply experimental error. The result of this analysis had little, if any, bearing on accounting for the sulfide loss. Therefore, it is necessary to seek the discrepancy elsewhere.

The sulfide concentration of the original mixture was determined on the total mixture whereas all other analysis were made on the supernatant liquid. It appeared that some organically bound sulfide might have been measured in the original analysis. The test was repeated therefore, using consistent sampling procedures, i.e., sampling of supernatant in all instances. The results of the repeated test are shown in Table 17B.

An almost exact balance of sulfur species was found between start and end of the aeration period.

Test 2 shows that the oxidation of sulfide by acclimated activated sludge is rapid and fairly complete under the conditions of the test. In Test 2A 61.5 percent of the initial sulfide was converted to sulfate, 5.5 percent was lost in the exhaust gas, 1 percent was unchanged and 22 percent is unaccounted for and presumably is absorbed by the sludge. Facilities were not available for a complete analysis of the sludge. In Test 2B in which only the supernatant liquid was considered the conversion of sulfide to sulfate was 86 percent with 13 percent unchanged and 1 percent unaccounted for.

The results of Test 2 along do not demonstrate the fact that the oxidaton is a biological process. It does not exclude the possibility of catalytic air oxidation with the sludge providing the catalyst.

## Test 3

The previous test indicated that the presence of activated sludge is effective in the oxidation of sulfide. However, it was not known whether only the living organisms were responsible for this or if killed organisms could bring about the same result. The purpose of Test 3 was to investigate this feature of the process.

Procedure - Test 3 repeated essentially the same procedure used in the previous test with one exception. The activated sludge mixed liquor from the pilot plant aeration tank was first boiled for about five minutes before it was used. After the boiled mixed liquor had been cooled, sodium sulfide stock solution was added to it and the mixture was aerated as before. Samples of the supernatant liquid were collected as in previous tests. The results of analyses of this test are presented in Table 18.

## TABLE 18. TEST RESULTS - AERATION OF SOLUTION OF COMMERCIAL SODIUM SULFIDE IN HEAT KILLED ACTIVATED SLUDGE MIXED LIQUOR

### TEST 3

| Aeration Period (min) (1) | Iodine Demand mg/l as $S^=$ (2) | Sulfide mg/l as $S^=$ (3) | Sulfate mg/l as $S^=$ (4) | Hydrogen Sulfide mg/l as $S^=$ (5) | Total 2,3,4,5 mg/l as $S^=$ (6) |
|---|---|---|---|---|---|
| 0 | 217 | 207 | 114 | 0 | 321 |
| 22 | | | | 22.9 | |
| 40 | 141 | | | | |
| 55 | 106 | 90 | 131 | 36.8 | 257.8 |
| 115 | 67 | 24 | 138 | 46.8 | 208.8 |

Note: pH initial 8.1 pH final 8.8

## TABLE 19. TEST RESULTS - AERATION OF SOLUTION OF COMMERCIAL SODIUM SULFIDE IN ACID KILLED ACTIVATED SLUDGE MIXED LIQUOR

### Test 4

| Aeration Period (min) (1) | Iodine Demand mg/l as $S^=$ (2) | Sulfide mg/l as $S^=$ (3) | Sulfate mg/l as $S^=$ (4) | Hydrogen Sulfide mg/l as $S^=$ (5) | Total 2,3,4,5 mg/l as $S^=$ (6) |
|---|---|---|---|---|---|
| 0 | | 127 | 159 | 0 | 286 |
| 30 | | 30 | 150 | 25.6 | 205.6 |
| 170 | | 13 | 164 | 33.3 | 210.3 |

Note: pH initial 8.0

The amount of sulfide removed amounted to 183 mg/l. The amount of sulfur recovered as increased sulfate and sulfide expelled amounted to 70.8 mg/l. Thus, about 112 mg/l of sulfide removed remained unaccounted for. About 89 percent of the sulfide was removed in 115 minutes aeration. Only 12 percent was oxidized to sulfate compared to 61.5 percent in Test 2 where live bacteria were present. On the other hand, 23 percent of the sulfide was expelled as $H_2S$ gas compared with only 5.5 percent in Test 2. However, 54 percent was unaccounted for compared to 1 percent unaccounted for in Test 2.

The above results suggest that the activated sludge solids can absorb the sulfide but do not oxidize it to sulfate in the absence of live bacteria or oxidize it at a slow rate. The observation that 23 percent of the sulfide was expelled as $H_2S$ gas further suggests that the absorption is not rapid and may not be complete.

## Test 4

Boiling is one method of killing the activated sludge organisms. Boiling also causes physical and chemical changes to occur to the sludge substance. It was desirable to learn if these side effects of boiling effected the ability of the sludge to oxidize sulfide to sulfate. Hence, another method of inactivating the sludge was explored. In Test 4, the ability of the activated sludge to oxidize sulfide to sulfate was tested after the sludge had been killed with hydrochloric acid.

Procedure - To two liters of fresh mixed liquor was added 25 ml of concentrated hydrochloric acid. This was sufficient to reduce the pH of the mixed liquor to 1.2. The mixed liquor was allowed to stand for two hours in this condition with occasional mixing. After this time about 25 ml of 45 percent sodium hydroxide solution was added to bring the pH of the mixture back to the original value of 7.1. Then sodium sulfide solution (adjusted to pH 9) was added in the proportion of 100 ml per liter of mixed liquor.

Aeration of the mixture was started in the usual manner but because of excessive foaming the test was stopped.

Aeration was begun agina on a reduced volume of the mixture to which was added about 2 ml of antifoam compound.

The results of Test 4 are presented in Table 19. From Table 19 it may be seen that 170 minutes of aeration resulted in a reduction of the sulfide concentration from 127 mg/l to 13 mg/l, a reduction of 90 percent. At the same time, the sulfate concentration increased by only 5 mg/l and the hydrogen sulfide gas expelled amounted to 33.3 mg/l. The total reduction of sulfide was 114 mg/l while the accounted for increases amounted to 38.3 mg/l. Hence it may be assumed that 75.7 mg/l was absorbed into the activated sludge floc but not oxidized to sulfate.

## Further Testing

In addition to the tests reported above, in which the rate of sulfide removal was studied, another series of tests was conducted which involved added sodium sulfide. This series studied the rate of utilization of oxygen by organisms oxidizing sulfide solutions. The description of the apparatus and procedures will be discussed later under the heading "Oxygen Uptake Tests." It will be shown later that an immediate increase in the rate of utilization of oxygen takes place upon the addition of sulfide to a sample of mixed liquor. The oxygen used was equal to or slightly greater than the amount required for the stoichiometric conversion of sulfide to sulfate, according to the reaction:

$$S^{=} + 2O_2 \longrightarrow SO_4^{=}$$

## Conclusions

The organisms in the activated sludge of the pilot plant have a profound effect in the oxidation of sulfide. It appears that an alteration of the sulfide occurs even after the organisms have been killed. Since all of the sulfide loss could not be accounted for as sulfate or evolved sulfide, in the cases where the sludge had been killed, the tests suggest that the oxidation of sulfide to sulfate is not direct. Further, it would appear that live organisms are required to complete the oxidation of sulfate under the conditions studied.

It is evident, however, that aeration of the sulfide waste without activated sludge will not result in a sufficiently rapid oxidation of the sulfide to provide a practical method for disposal of sulfides and would probably result in sulfide odors.

Biological treatment of the waste is essential therefore, for both removal of organic BOD and sulfide.

## OXYGEN UPTAKE STUDIES

### General

Activated sludge treatment is a method of utilizing a controlled biological process for the oxidation of the putresible organic matter in wastes. Microorganisms convert the organic matter to cellular materials, carbon dioxide, and water. In so doing the biological reactions release energy that can be utilized by the organisms for growth and reproductive functions. The overall oxidation of food for growth and energy, i.e., the metabolism of the organisms, results in a reduction in the amount of organic matter, some of which is converted to carbon dioxide and water.

The rate of metabolism of any particular group of aerobic organisms is dependent upon the amount of oxygen, food, nutrients, growth inhibitors and the number of organisms present in the biological medium. The rate of oxygen uptake is directly related to the rate of metabolism and, therefore, provides a means of measuring the effects of the various factors limiting metabolism. Some of these factors and their relationship to the tannery waste are described in the succeeding paragraphs.

Oxygen uptake rates for the activated sludge system in the pilot plant were studied under varying conditions of food addition. Included in the tests was a test of the uptake rate during the endogenous phase of growth. In the endogenous phase the ratio of food concentration to the mass of the microorganisms is small.

As important as food and oxygen are to growth, nutrients are almost equally important. The nutrients include nitrogen and phosphorous and trace quantities of potassium, calcium, magnesium, molybdenum, cobalt, and iron. Normal contamination of process chemicals ensures that these trace elements will be present in adequate amounts. It is generally accepted that a waste contains sufficient nitrogen and phosphorous to sustain bacterial metabolism if the nitrogen is present in the ratio of 1 part to 25 parts of COD (chemical oxygen demand) and the phosphorous is present in the ratio of 1 part to 100 parts of COD. If the validity of these ratios is accepted, it can be seen (Table 20) that the phosphorous requirement was not met by the tannery waste. For this reason an investigation was made of the effects of additional phosphorous on the rate of oxygen uptake.

In addition to the factors already discussed, which would tend to stimulate growth, some factors which might inhibit growth were also investigated. Calcium, sulfide, and chromate have been known to slow the rate of metabolism of microorganisms. These were studied in the concentrations which might be found in the tannery waste.

In order to investigate the effects of these chemicals, exact measurements of oxygen uptake under controlled conditions were necessary. Such measurements could not be made in the pilot plant. The tests were, therefore, conducted on a laboratory scale with apparatus assembled specifically for this purpose.

## Apparatus

Fig. 18 is a diagram of the apparatus used in the tests. Duplicate units were used. One was used as a control and was denoted "barometer." It was similar in all respects to the "sample" unit with the exception that no stirrer was required for the barometer.

Each unit consisted of a vacuum filtering flask, the sidearm of which was connected to a 3 ft length of 6 mm O.D. glass tubing which was supported vertically. The lower end of the tubing was immersed in a water reservoir in order that it would serve as a manometer. The upper end of the tubing was vented through a short piece of rubber hose provided with a pinch clamp. Each of the flasks were immersed in a water bath to just below the sidearm to stabilize temperature fluctuations.

The sample flask was fitted with a rubber stopper. This was used for a support for a small cup reservoir that was suspended just below the neck of the flask. Mixing and aeration of the contents of the sample flask was provided for by using a magnetic stirring device with a teflon coated stirring bar in the flask. The barometer flask was sealed with a rubber stopper also but no reservoir was provided within the flask.

## General Procedure

A sample of mixed liquor from the activated sludge unit of the pilot plant was introduced into the reaction flask. 3 ml of a 50 percent potassium hydroxide solution was placed in the cup reservoir. The upper inside wall of the reservoir had been greased previously to prevent "creeping out" of the solution over the wall. The stopper and reservoir assemblage were carefully and securely fixed in the neck of the flask. Extreme care was taken to prevent the slightest contamination of the sample with potassium hydroxide.

A volume of water equivalent to the sample volume was introduced into the barometer flask after which the flask was securely stoppered. Mixing of the sample by means of the magnetic stirrer was begun. Then both manometers were adjusted so that the water level inside and outside the manometers coincided and the vents were clamped shut immediately.

As the test progressed, the oxygen dissolved in the sample mixture was taken up by the organisms. This was replaced by oxygen from the air within the flask and resulted in a pressure loss in the system. Any carbon dioxide produced as a result of metabolism was absorbed by the potassium hydroxide solution. At frequent intervals the pressure decrease in the sample flask was noted from the manometer reading. At the same time, the barometer and thermometers in the stabilizing baths were read.

The pressure drop in the flask represented oxygen used. The amount of oxygen used was computed by the ideal gas relationship:

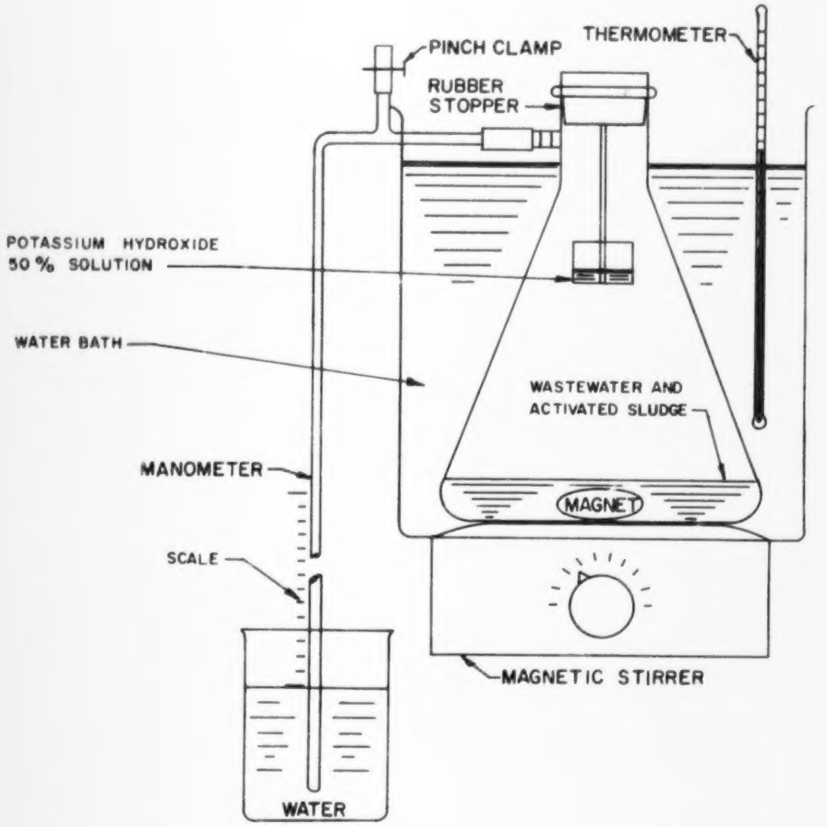

PINCH CLAMP
THERMOMETER
RUBBER STOPPER
POTASSIUM HYDROXIDE 50 % SOLUTION
WATER BATH
WASTEWATER AND ACTIVATED SLUDGE
MANOMETER
MAGNET
SCALE
MAGNETIC STIRRER
WATER

FIG. 18 OXYGEN UPTAKE APPARATUS

$$PV = nRT$$

where

$P$ = pressure in atmosphere
$V$ = volume in liters
$T$ = temperature in degrees Kelvin
$n$ = number of moles of gas
$R$ = gas constant, liter-atmosphere/mole degree K.

Another formula was derived from this which takes into account corrections for atmospheric pressure changes, corrections for temperature changes, the volume of the units, and the relationship between the volume of oxygen and its weight under standard conditions of temperature and pressure (0°C and 1 atmosphere). The formula equates the observed values directly with the weight of oxygen consumed and is shown here:

$$\text{mg } O_2 = 390 \frac{Vi}{Ti} - \frac{[406.8 - (mr-br)]\ [Vi - 0.68\ (mr-br)]}{406.8T_f}$$

where

br = inches of rise in barometer
mr = inches of rise in sample manometer
Vi = air volume of flask and tubing in ml
Ti = temperature of water bath at start of the test in °K
$T_f$ = temperature of water bath at time of readings in °K

By substitution of the observed values in the equation, the weight of oxygen used during each time period could be calculated.

Modifications of this general procedure are described in the discussions of the individual tests.

## Individual Tests

### Test 1

In order to establish a frame of reference for the tests, the first test was carried out under the conditions existing in the pilot plant.

A fresh sample of aeration tank activated sludge was introduced into the test apparatus within ten minutes of its collection. Following the general procedure already described, manometer readings were taken at definite intervals and were recorded. A plot of oxygen uptake versus time is given in Fig. 19. Note that the oxygen uptake is plotted as milligrams of oxygen per milligrams of mixed liquor volatile suspended solids. This method of reporting the results allowed for the comparison of the several tests where different microbial populations were present.

The rate of oxygen uptake in this test was 0.264 mg of oxygen per mg of mixed liquor volatile suspended solids per day.

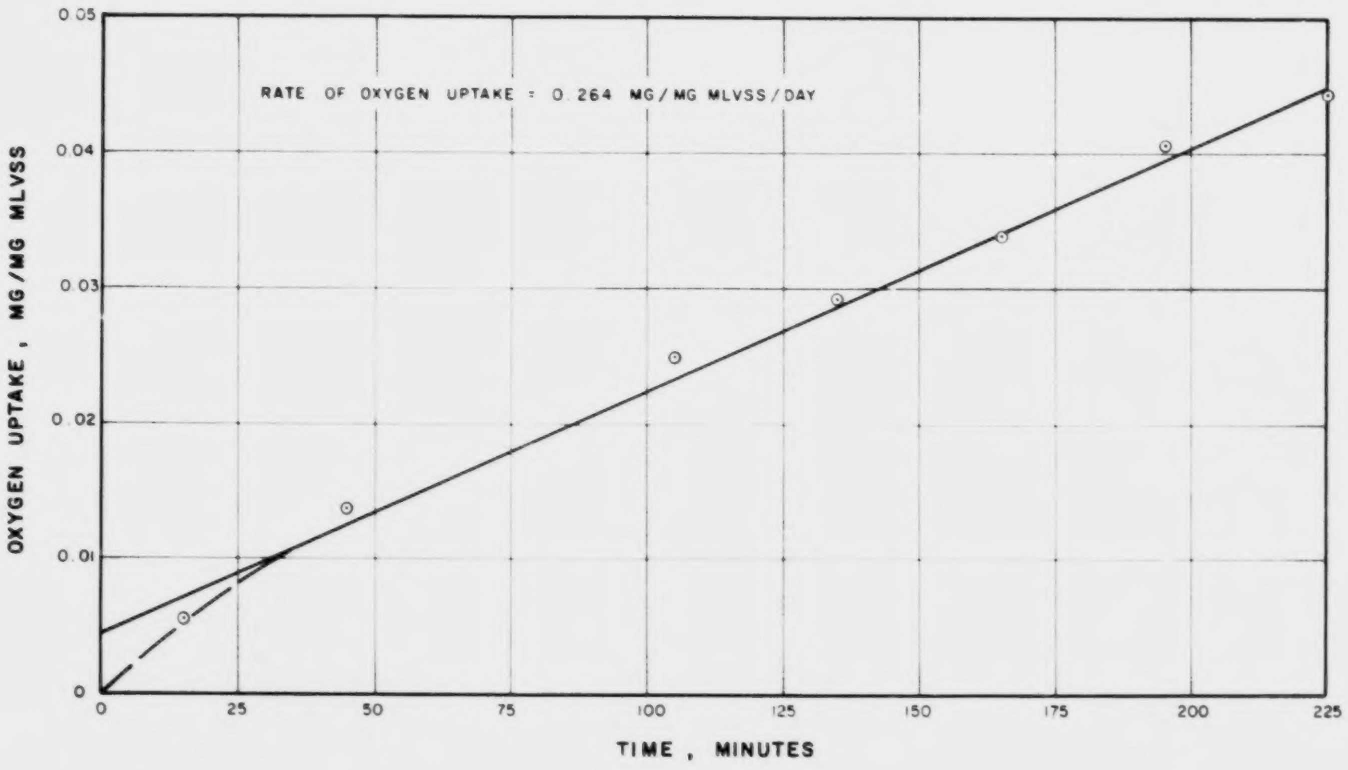


FIG. 19 PLOT OF OXYGEN UPTAKE VERSUS TIME WITH FRESH ACTIVATED SLUDGE (TEST I)

## Test 2

The purpose of the second test was to establish the rate of oxygen uptake under the conditions of endogenous metabolism. The activated sludge, after collection, was aerated for 15-1/4-hours in the laboratory without feeding before a portion of it was put on test. The results are presented graphically in Fig. 20. The average rate of oxygen uptake under the conditions of this test was 0.180 mg of oxygen per mg of mixed liquor volatile suspended solids per day.

## Test 3

In Test 3, pre-aeration of the activated sludge sample was carried out in the laboratory for 4.5 hours. This was done to reduce the food concentration present in the mixed liquor without carrying the organisms into the endogenous phase. At the end of 4.5 hours aeration, equal volumes of the aerated activated sludge and carbonation tank effluent were introduced into the test apparatus. The amount of oxygen taken up over fixed intervals was determined and the results plotted. See Fig. 21.

In Test 3, the mixed liquor volatile suspended solids concentration was 2440 mg/l and the 5-day, 20°C BOD of the added wastewater was 900 mg/l. Under these conditions, the average rate of oxygen utilization for a period of two hours was about 0.55 mg/mg MLVSS/day. The oxygen uptake in the test was equivalent to 670 mg/l/day or abut 40 lbs/day/1000 cu ft of aerator capacity. A common figure used in the design of activated sludge aeration basins is 30 lbs of 5-day, 20°C BOD/day/1000 cu ft of aerator capacity. This test indicates that the tannery effluent and sewage mixture falls within the range of common experience.

## Test 4

Test 4 measured the rate of oxygen uptake of fresh activated sludge with addition of carbonation tank effluent. No aeration of the activated sludge was carried out after collection from the aeration tank until it had been combined in the apparatus with the carbonation effluent.

In Test 4, fresh activated sludge, containing about 1950 mg/l of mixed liquor volatile suspended solids, was mixed with waste having about 910 mg/l of 5-day, 20°C BOD and placed in the aeration apparatus. The volumetric ratio of activated sludge to waste was 2 to 1. The results of oxygen uptake measurement are shown in Fig. 22. The average rate of oxygen uptake for the first two hours of the test was equal to 1.44 mg/mg of MLVSS/day. The extremely high rate of uptake is no doubt due to unoxidized BOD contained in the sludge when it was removed from the aeration basin. This test indicates the rapid response to the sludge when slugs of food are added .

Translating this observation to plant design leads to the conclusion that the aeration system should be designed to rapidly increase its rate of

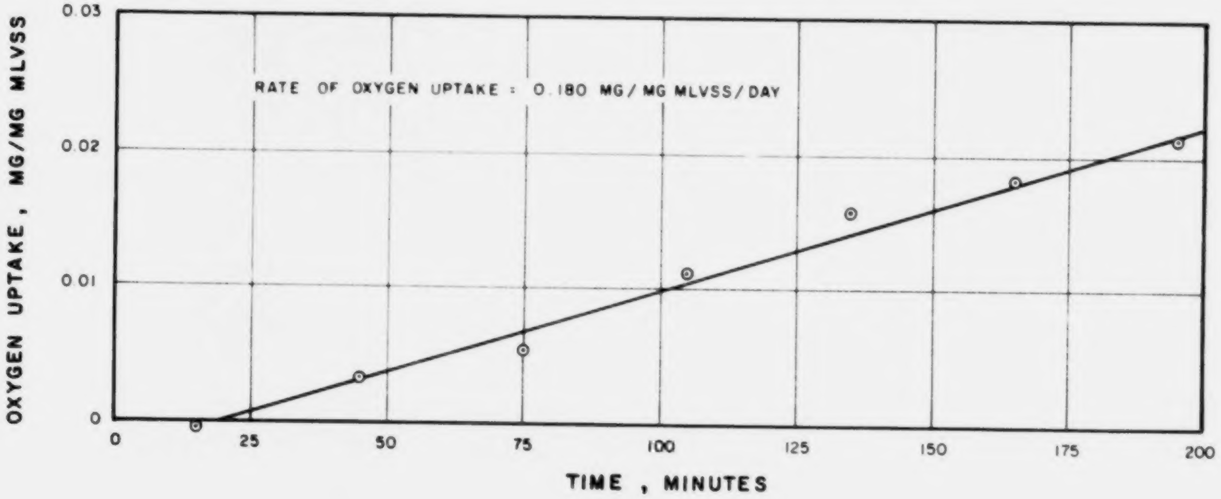


FIG. 20 PLOT OF OXYGEN UPTAKE VERSUS TIME WITH ACTIVATED SLUDGE IN ENDOGENOUS PHASE (TEST 2)

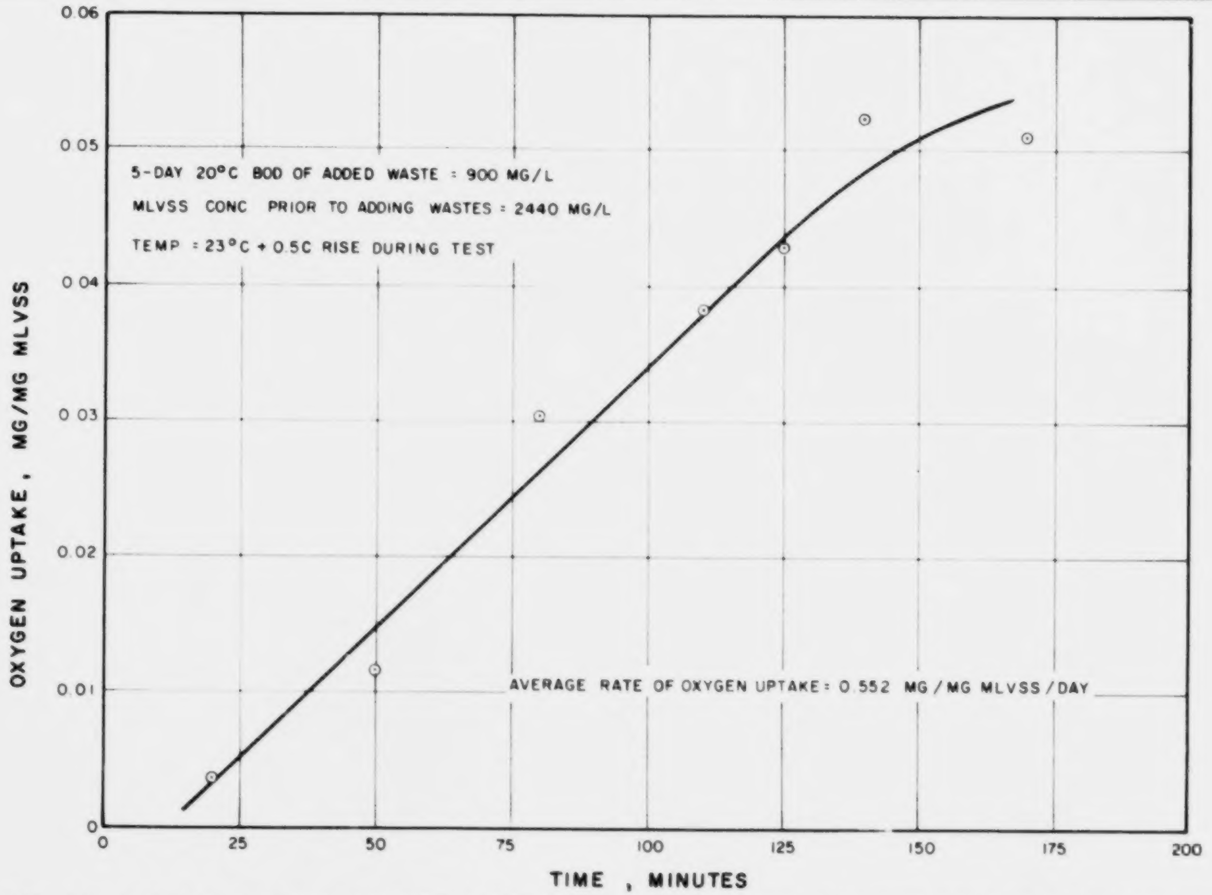


FIG. 21 PLOT OF OXYGEN UPTAKE VERSUS TIME FOR EQUAL VOLUME MIXTURE OF ACTIVATED SLUDGE AND CARBONATION BASIN EFFLUENT, SLUDGE AERATED 4.5 HRS PRIOR TO MIXING (TEST 3)

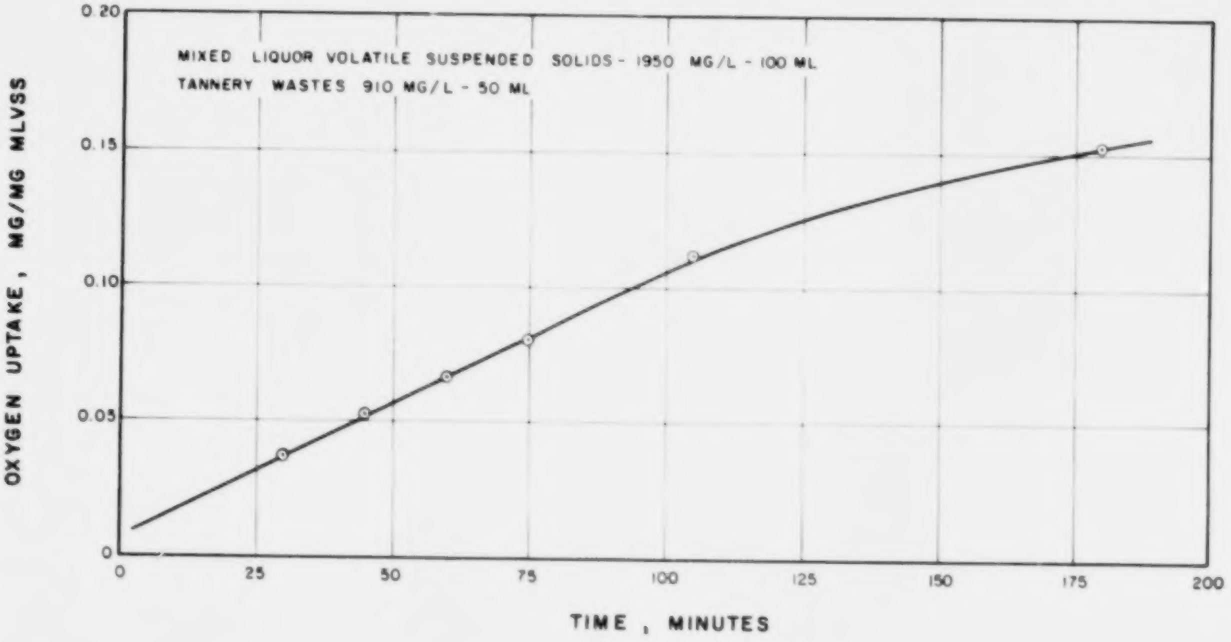


FIG. 22 PLOT OF OXYGEN UPTAKE VERSUS TIME FOR MIXTURE OF 2 PARTS FRESH ACTIVATED SLUDGE AND 1 PART CARBONATION BASIN EFFLUENT (TEST 4)

oxygen transfer to match the oxygen demand of slugs of high BOD, which occur frequently in the tannery discharges, or the treatment plant should minimize the occurrence of slugs by equalization of flow and waste quantity.

Tests 5, 6, 7

In Test Nos. 5,6 and 7 the response of activated sludge to the addition of commercial sodium sulfide was studied. The following procedure was used in these tests. 100 ml of fresh activated sludge from the pilot plant was placed in the test apparatus. The apparatus was closed and the sludge aerated for 1.5 hours. During this initial aeration period readings were taken of the oxygen uptake to obtain a base line. At the end of the initial period, the apparatus was opened and a few milliliters of a strong sodium sulfide, (2.5 grams/l sulfide) adjusted to pH 8.5, were added to the sludge. The apparatus was closed and the aeration and oxygen uptake measurements were resumed.

In Test Nos. 5,6 and 7, sulfide additions of 2,5 and 10 ml were made respectively. The sodium sulfide solution concentration was 2500 mg/l so that based on 100 ml of sludge the concentrations used in the tests were 50, 150 and 250 mg/l of sulfide added. After sulfide addition, readings were taken for an additional 1.5 to 17 hours. The results of Tests Nos. 5,6 and 7 are shown on Figs. 23 and 24. Fig. 23 presents the results of the initial results and Fig. 24 shows the long term results.

From the results of the oxygen uptake measurements for Tests Nos. 5,6 and 7 shown in Fig. 23 it may be computed that the rate of oxygen uptake prior to the addition of sulfide ranged from 0.18 mg $O_2$/mg of MLVSS/day for Test 6 up to 0.43 mg $O_2$/mg of MLVSS/day for Test 5. After the sulfide was added the uptake rates increased sharply. The rate for Test 5 was 1.35; for Test 6 the rate was 0.95 and for Test 7 the rate was 0.82. In other words, the addition of sulfide increased the rate of oxygen uptake 3 to 5 fold.

Furthermore, Tests Nos. 5 and 7 were carried to the point that the rate of oxygen uptake returned to approximately that of the fresh activated sludge. (See Fig. 24 for the end of Test No. 7). The amounts of oxygen consumed during the time required for the uptake rates to return to more normal levels was reasonably equivalent to the amounts needed to convert sulfide to sulfate. These observations support the results of the tests made to determine the fate of the sulfide in the activated sludge process.

Tests Nos. 5,6 and 7 point out the importance of preventing slugs of high oxygen demand sulfide from entering the aeration system. The best method of prevention is equalization which causes changes in concentration to be gradual.

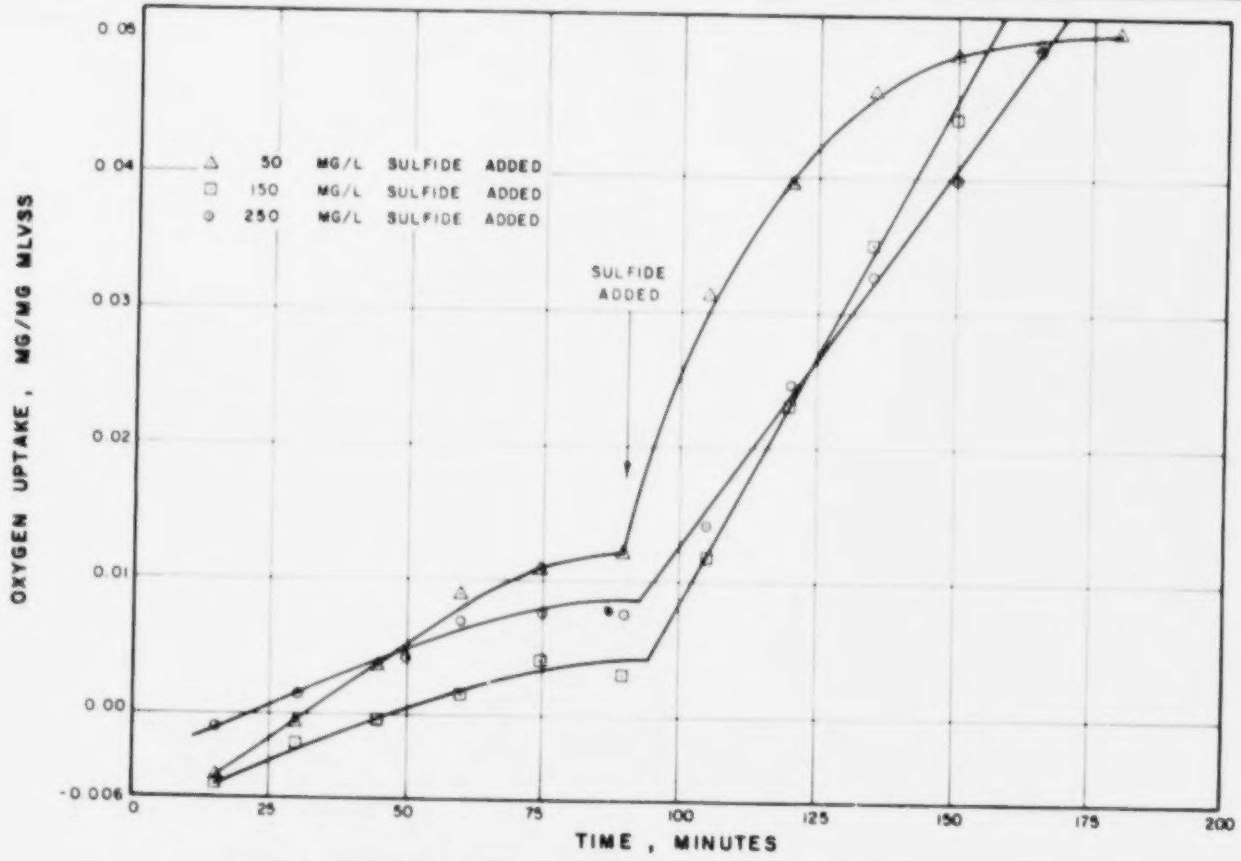


FIG. 23 PLOT OF OXYGEN UPTAKE VERSUS TIME BEFORE AND AFTER ADDING SODIUM SULFIDE TO FRESH ACTIVATED SLUDGE (TESTS 5, 6 AND 7)

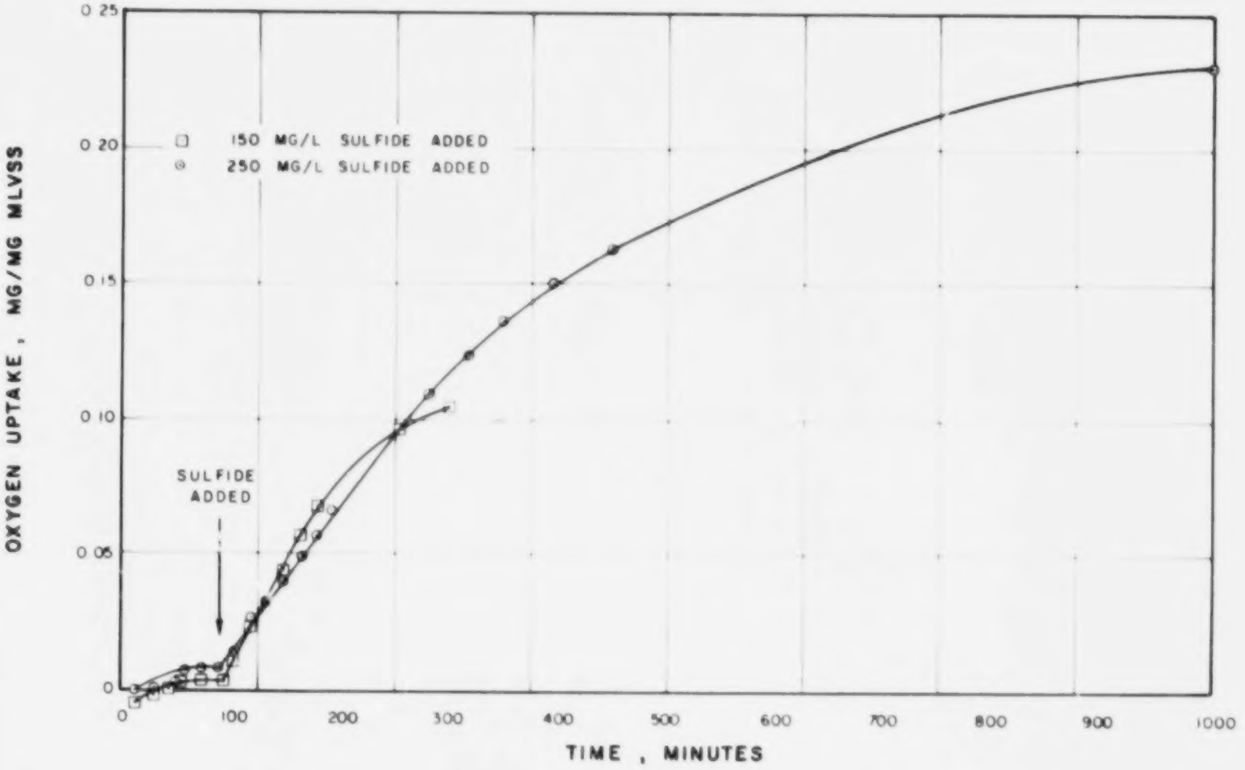


FIG. 24 PLOT OF OXYGEN UPTAKE VERSUS TIME BEFORE AND AFTER ADDING SODIUM SULFIDE TO FRESH ACTIVATED SLUDGE (TEST 6 AND 7)

### Tests 8 and 9

These tests were designed to determine the effect of phosphate added to the sludge. The procedure was the same as that used in the sulfide tests (Tests Nos. 5,6 and 7). Phosphate was added as a solution of disodium phosphate ($Na_2H PO_4$) containing 500 mg/l of phosphorous. After establishing the basic oxygen uptake rate, 1 ml (Test 8) and 3 ml (Test 9) of the phosphate solution were added to the activated sludge in the apparatus. Based on the 100 ml of sludge used this provided a phosphorous concentration of 5 mg/l in Test 8 and 15 mg/l in Test 9. The plotted results appear in Fig. 25.

From the results of Test Nos. 8 and 9, it appears that the addition of phosphate, in the form of disodium phosphate, has little, of any, effect on the short time oxygen uptake rates. These results indicate that although the phosphate concentration in the activated sludge system is somewhat low according to generally accepted standards it is high enough to cause the sludge to function in a satisfactory manner. This observation is supported by the fact that no readily apparent increase in efficiency of the activated sludge system was noted when the phosphate to the system was supplemented for a period of several weeks. (See Figs. 6 and 7).

Short term tests such as this for phosphate may not be the best evidence for the effects of phosphate. Additional time may be needed for the added phosphate to be incorporated in the metabolic cycle of the bacteria.

### Tests 10, 11 and 12

The influence of calcium on the rate of oxygen uptake was next studied according to the procedure of Tests 8-12. The possibility of calcium inhibiting oxygen uptake prompted this investigation.

One, two and three ml of a solution of calcium chloride (7500 mg/l as Ca) were added in the established manner in Tests 10, 11 and 12, respectively. Since calcium, of itself, would not create an oxygen usage by the organisms, it was necessary to add 50 ml of carbonation effluent to the 100 ml of activated sludge. Thus, an uptake rate would be established and any deviation from this rate upon adding calcium would be due to the inhibition of calcium on metabolism.

The procedure for conducting Tests Nos. 10, 11 and 12 was as follows:

1. 100 ml of fresh activated sludge were added to the aeration apparatus.
2. 50 ml of carbonation-basin effluent were added.
3. Aeration was started and uptake measurements were made for about 90 minutes to establish a baseline.

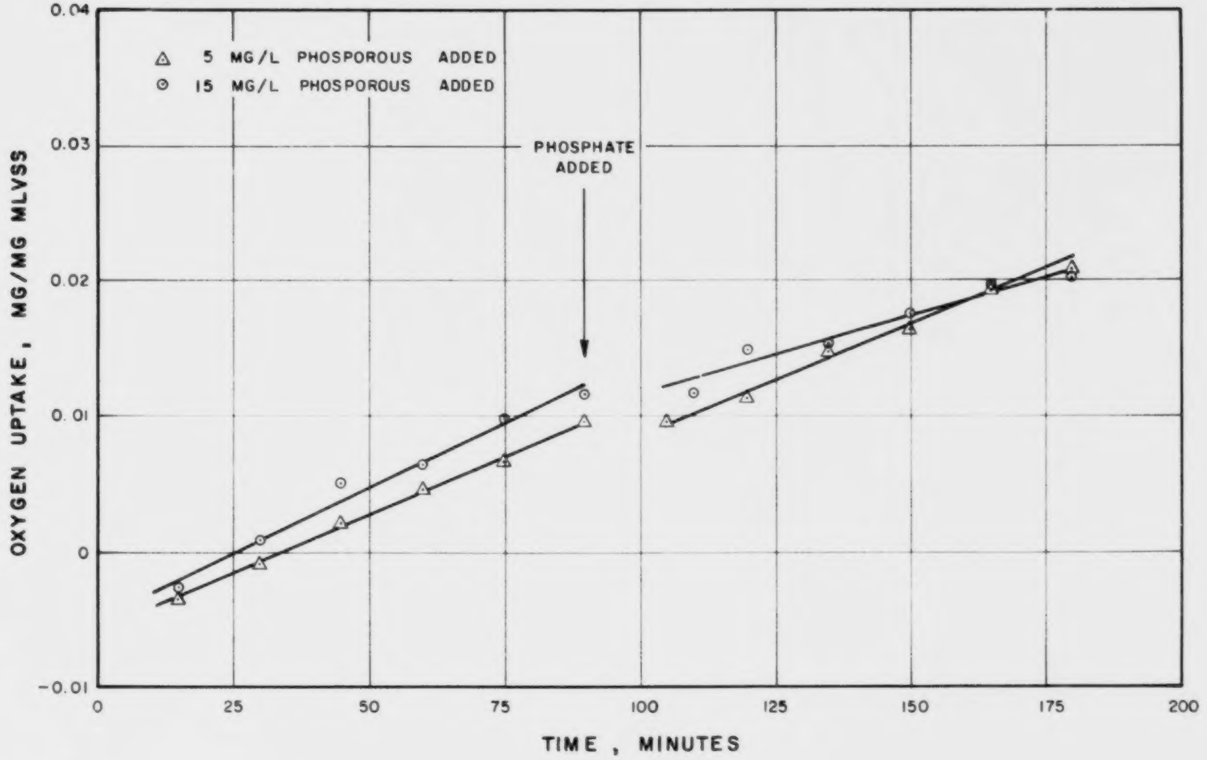


FIG. 25 PLOT OF OXYGEN UPTAKE VERSUS TIME BEFORE AND AFTER ADDING PHOSPHATE TO FRESH ACTIVATED SLUDGE ( TEST 8 AND 9 )

4. A solution of calcium chloride was added and uptake measurements continued.

The results of these tests are presented in Fig. 26.

From Fig. 26, it may be seen that the rates of oxygen uptake did not change significantly after the addition of the calcium. Any reduction in rate which might appear to have occurred is probably due to the gradual reduction in the initial food concentration with time.

Although calcium does not appear to have a significant short-term effect on the activated sludge system, it is our opinion that an accumulation of calcium carbonate in the sludge over a period of time will have a detrimental effect.

The detrimental effect of calcium will, in our opinion, be due to an accumulation of calcium carbonate in the recirculated activated sludge increasing the nonvolatile and nonactive portions of the sludge mass. At this time it has not been determined where a balance will occur between the added calcium and the accumulated calcium carbonate. In a full scale treatment plant this possibility should not be overlooked when evaluating operating characteristics.

### Test 13

In this final test, the effect of chromium on the oxygen uptake was determined. As in the previous tests, carbonation effluent was added to the sludge in the apparatus to provide food for the microorganisms. At the start of the test readings were taken with the mixture of 50 ml carbonation effluent and 100 ml of activated sludge. At the end of 90 minutes, 1 ml of solution of chrome liquor (a dilution of the tannery prepared liquor) containing 15 gm/l of chromium was added to the mixture in the apparatus. This represented a concentration of 100 mg/l of chromium. As in previous tests, oxygen uptake readings were taken for another 90 minutes.

The results are shown in Fig. 27.

From Fig. 27, it may be seen that no change occurred in the rate of oxygen uptake before or after the addition of excess chromium. These observations are in accordance with the experience of others.(9) Furthermore, it should be pointed out that the chromium in the tannery liquors is completely in the tri-valent state.

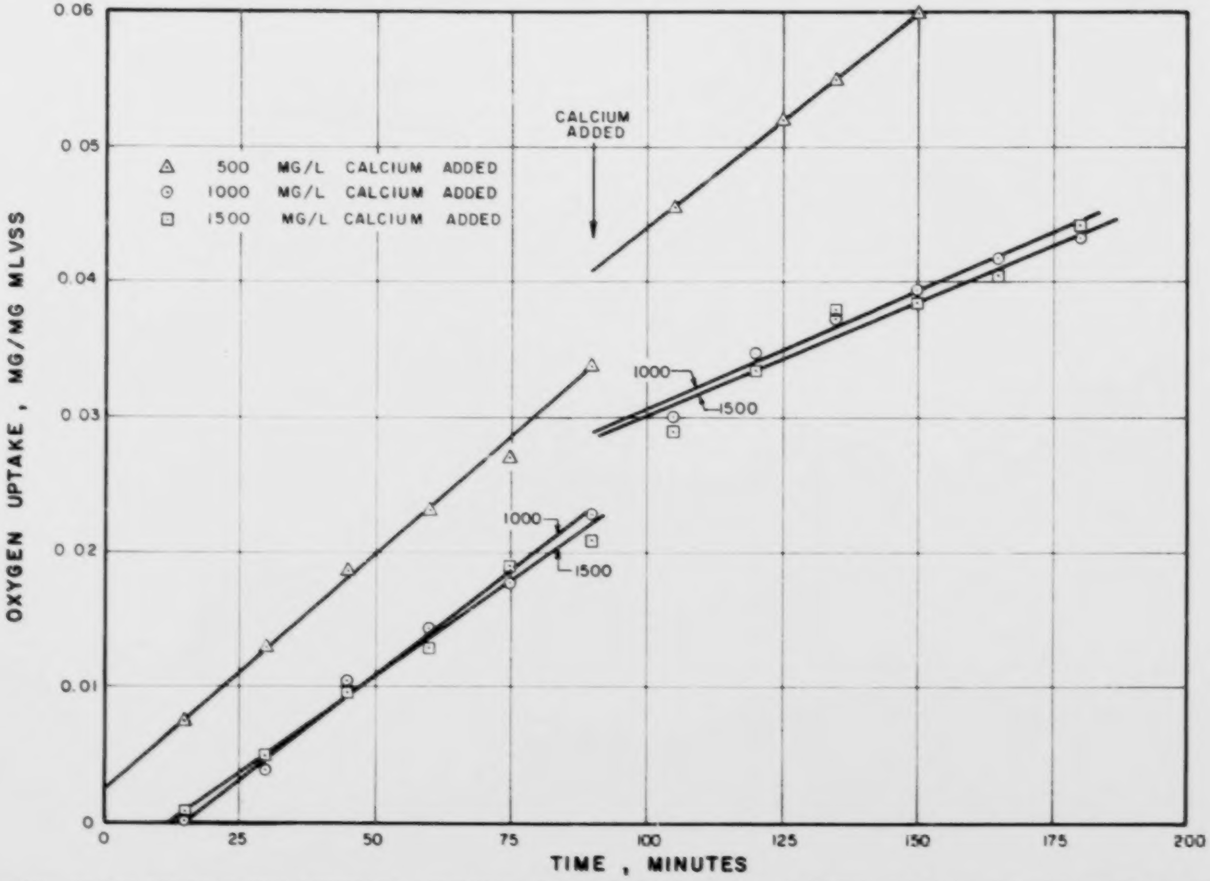


FIG. 26 PLOT OF OXYGEN UPTAKE VERSUS TIME BEFORE AND AFTER ADDING CALCIUM TO MIXTURE OF 2 PARTS FRESH ACTIVATED SLUDGE AND 1 PART CARBONATION BASIN EFFLUENT (TEST 10, 11, 12)

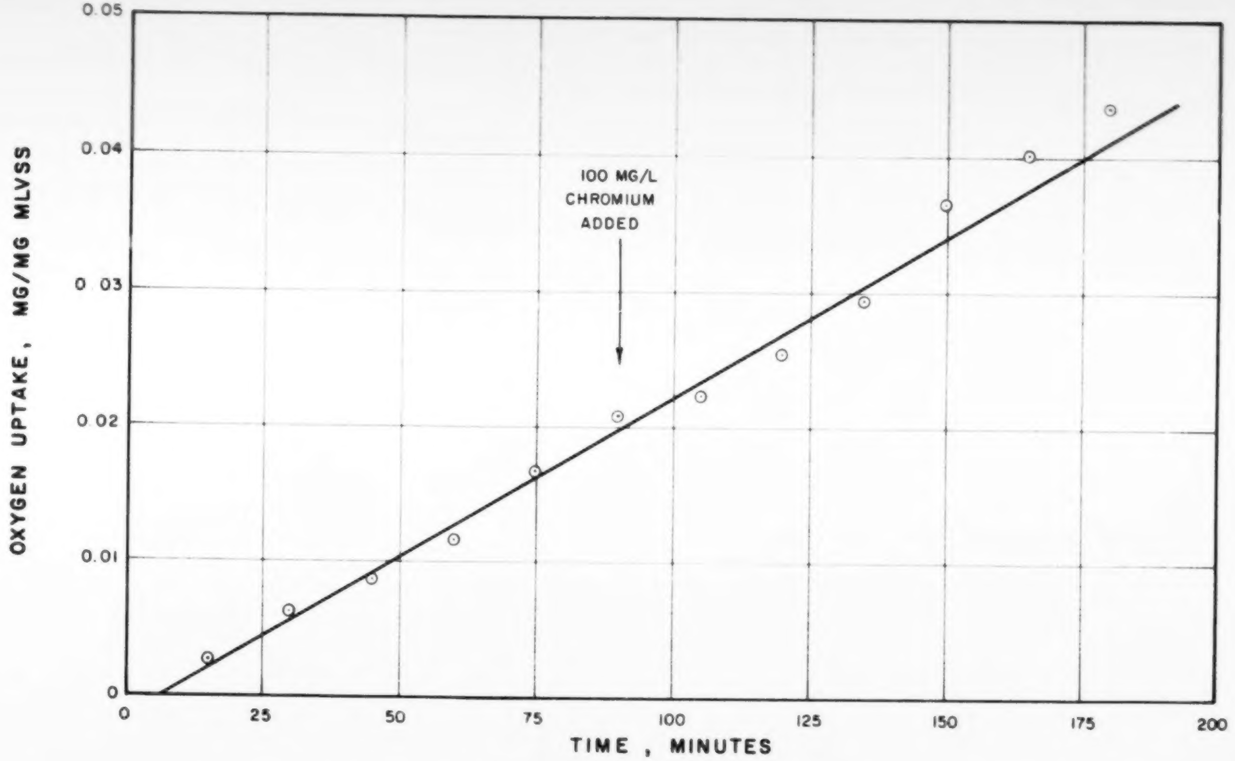


FIG. 27 PLOT OF OXYGEN UPTAKE VERSUS TIME BEFORE AND AFTER ADDING 100 MG/L CHROMIUM TO A MIXTURE OF 2 PARTS FRESH ACTIVATED SLUDGE AND 1 PART CARBONATION BASIN EFFLUENT (TEST 13)

## NUTRIENTS

The effluents from the tannery are rich in protein material, dissolved from the animal skins. Protein matter is readily metabolized by the organisms found in the activated sludge process. Proteins contain adequate amounts of nitrogen to meet the nutritional needs of the activated sludge organisms. However, there is some question as to the adequacy of the phosphorous in the waste needed to meet the nutritional requirements for this element. Table 20 presents a number of analyses of the waste in various stages of treatment indicating the amounts of COD, nitrogen and phosphorous present. The samples analyzed were typical of a number of eight hour composites taken for this purpose.

From Table 20, it may be seen that the total phosphorous in the untreated effluent varied from 4.0 to 22.4 mg/l. On passage through the primary system the phosphorous content decreased to between 5.6 to 4.8 mg/l. The decrease was probably due to settling out of insoluble calcium phosphate. The primary system sludges contained about 0.12 percent phosphates, as phosphorous.

The COD to phosphate ratio in the waste leaving the primary system varied from 300 to 323. The amounts of phosphorous in the sanitary sewage are not known; however it has been estimated that the concentration may be between 4 to 9 mg/l. (12) On the basis that the sewage containing 6 mg/l of phosphorous is mixed with the tannery waste following sedimentation and carbonation in the ratio of 1 to 4 the resulting ratio of COD to P will be about 75 to 1. These estimates indicate the importance of mixing sanitary sewage with the tannery wastes in order to provide a nutritionally balanced waste for biological treatment.

Many biologists and sanitary chemists consider that the minimum COD/P ratio for a successful activated sludge is 100 and the minimum COD/N ratio is 25. If one accepts the above values it is apparent that the tannery effluent entering the activated sludge process (carbonation effluent) is deficient in phosphorous, but adequate in nitrogen. The sanitary sewage serves to make up the deficiency. A study of the phosphorous content of the plant effluent indicates that the COD/P ratio decreased greatly in passage through the plant to about 50. On the other hand, the volatile solids/phosphorous ratio (roughly equivalent to COD/P ratio) of the sludge removed from the secondary system was 360 (see Table 13) indicating that little, if any, phosphorous was being extracted and retained in the sludge.

From June 18, through July 12, extra phosphate in the amount of 3.25 mg/l P was added to the aeration basin. No significant increase in BOD removal was noted for this period. However, the suspended solids in the secondary effluent decreased to the lowest level observed during the pilot plant operation. A survey of the literature on the subject indicated that low

## TABLE 20. ANALYSES OF TANNERY WASTEWATERS FOR NITROGEN, PHOSPHORUS, AND COD

| Source | Untreated | Primary Effluent | Carbonation Effluent | Plant Effluent | Untreated | Primary Effluent | Carbonation Effluent | Plant Effluent | Untreated | Primary Effluent | Carbonation Effluent | Plant Effluent |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | 5/6/68 | 5/6/68 | 5/6/68 | 5/6/68 | 5/14/68 | 5/14/68 | 5/14/68 | 5/14/68 | 5/23/68 | 5/23/68 | 5/23/68 | 5/23/68 |
| Total Phosphate as P, mg/l | 22.4 | 7.2 | 5.20 | 4.8 | 9.6 | 14.0 | 5.6 | 1.2 | 4.0 | 5.6 | 4.8 | 5.2 |
| Polyphosphate as P, mg/l | 18.9 | 6.68 | 4.32 | 4.66 | 3.6 | 8.5 | 4.0 | 1.0 | 1.6 | 3.3 | 3.2 | 4.2 |
| Total Nitrogen as N, mg/l | 145 | 116 | 105 | 52 | 105 | 102 | 106 | 35.8 | 128 | 112 | 93.1 | 46.0 |
| Ammonia as N, mg/l | 14.2 | 16.8 | 16.8 | 12.9 | 18.3 | 16.8 | 17.6 | 25.4 | 7.9 | 10.8 | 10.4 | 3.4 |
| Nitrates as N, mg/l | 0.30 | 0.20 | 0.18 | 0.09 | 0.54 | 0.36 | 0.15 | 0.03 | 0.31 | 0.10 | 0.10 | 0.01 |
| Nitrites as N, mg/l | 0.003 | 0.003 | 0.003 | 0.13 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 | 0.003 |
| COD | 3,050 | 1,870 | 1,560 | 118 | 3,060 | 1,930 | 1,810 | 168 | 1,960 | 2,000 | 1,490 | 215 |
| COD/P Ratio | 136 | 260 | 300 | 25 | 319 | 138 | 323 | 140 | 490 | 358 | 310 | 41 |
| COD/N Ratio | 21 | 16 | 15 | 2 | 29 | 19 | 17 | 5 | 15 | 18 | 16 | 5 |

Note: The "Untreated Wastes," the "Primary Effluent" and the "Carbonbonation Effluent" consisted of tannery wastewater. The "Plant Effluent" included municipal sewage and tannery wastewater.

COD/N and COD/P ratios in activated sludge favor the development of fungi, which do not settle well but are efficient in removal of BOD from solution. Such was probably the cause of the results observed in the pilot plant during periods of poor secondary sludge settleability.

On the basis of these results, it is recommended that equipment and facilities be included in the full scale treatment plant to add phosphates to the activated sludge unit as needed. The equipment should have the capacity to add up to 15 mg/l of phosphorous. Such facilities would only be used if needed.

# FLUE GAS UTILIZATION

## General

The efficiency of the carbonation unit is primarily dependent upon the rate of transfer of carbon dioxide between the flue gas and the wastes. The amount of flue gas required to treat the waste can be computed only with the knowledge of transfer rate of the carbon dioxide in the system.

The rate of transfer of a gas into a liquid may be expressed as:

$$\frac{dC}{dt} = k_1 \; a \; (C_s - C) \qquad (1)$$

Where

$\frac{dC}{dt}$ = rate of change of gas concentration in the liquid, C the concentration of the gas dissolved in the body of the liquid.

$C_s$ = the concentration of the gas in the liquid at saturation

a = the gas-liquid interfacial area per unit volume of liquid

$K_1$ = the liquid-gas film coefficient

In the tests hereinafter described dC/dt, C, and a are measured. $C_s$ was taken from the literature. From the above data $K_1$ may be calculated.

Later it will be shown that when the pH of the carbonation mixture is maintained at or above pH 9, which is a condition for which there is essentially no dissolved carbon dioxide, C becomes zero and may be dropped from the equation. The concentration of carbon dioxide in the liquid at saturation concentration is 1495 mg/l at 25°C and 1 atmosphere pressure for pure $CO_2$ over water.

Rearrangement of equation (1) gives:

$$K_1 = \frac{a \; Cs}{\frac{dC}{dt}} \qquad (2)$$

and $K_1$ was determined by evaluating the other parameters.

Equipment - The tests were conducted in an 8 ft high clear plastic column as illustrated in Fig. 28. The inside diameter of the column was 5-3/8-in. At the bottom the column was sealed water tight using a plastic cap and gasket arrangement while the top of the column was closed with an overlapping wooden cap. Ports, fitted with rubber stoppers through which tubing could be passed, were located at various points on the column and in the wooden cap.

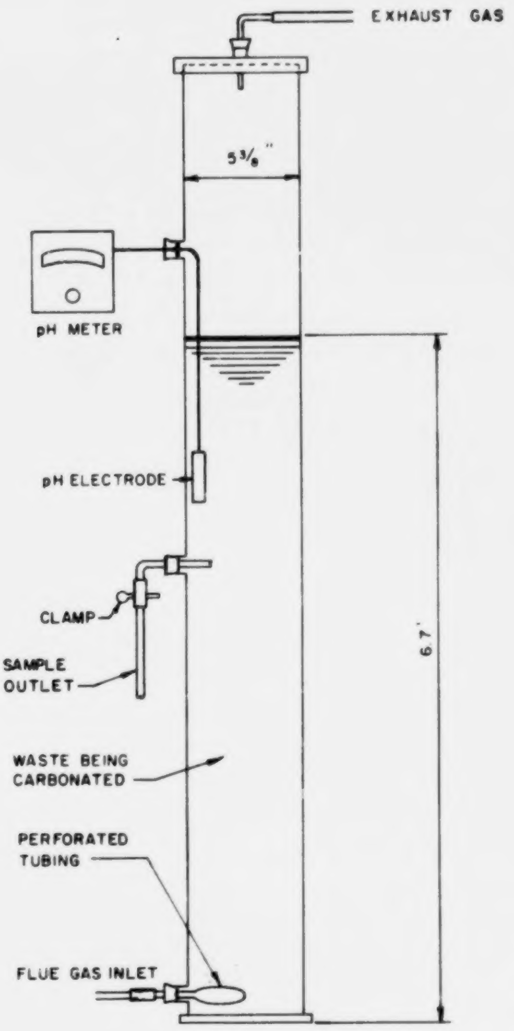

EXHAUST GAS
5 3/8"
pH METER
pH ELECTRODE
CLAMP
SAMPLE OUTLET
6.7'
WASTE BEING CARBONATED
PERFORATED TUBING
FLUE GAS INLET

FIG. 28 FLUE GAS UTILIZATION TEST APPARATUS

A ring shaped piece of rubber tubing was punctured in numerous places with a pin. This was anchored at the bottom and was connected through the bottom inlet to the source of flue gas. The perforated tubing served as the gas diffuser.

About half way up the column, a sampling tube was connected through one of the ports. This allowed for sampling the liqud contents of the column. Still further up the column, a pH electrode was passed through a port so that pH measurements of the liquid could be made throughout the test. Finally a rubber tube was attached through the wooden cap to serve as an exhaust for the wasted flue gas and to permit sampling of the exhaust gas.

An Orsat gas apparatus was employed to analyze the flue gas and the exhaust gas for carbon dioxide. Basically, the Orsat apparatus measures the volume of gas before and after absorption of carbon dioxide in a concentrated solution of potassium hydroxide. The difference in volume represents the fraction of carbon dioxide in the gas being analyzed.

Test Procedure - A thirty liter portion of a grab sample of the tannery waste, taken from the pilot plant influent, was placed in the column. A smaller portion of the sample was reserved for pH and alkalinity determinations. The column was capped and the flue gas was fed to the waste in the column. A sample of the flue gas was taken at the start of carbonation. Samples of the gas which had passed through the liquid were also collected during the test. A final sample of the influent flue gas was also taken at the end of the test.

During the period of carbonation, i.e., while the gas was bubbling through the waste, the pH was monitored and samples of the waste were collected for alkalinity tests. Carbonation was continued until the pH was reduced to about 8.5.

The average carbon dioxide content of the flue gas during the test was determined from the gas analysis. By subtracting the average carbon dioxide of the effluent gas from that of the influent, the amount of carbon dioxide transferred during the time of carbonation may be calculated. Thus, dC/dt is determined.

In order to determine (a) the interfacial area, it is necessary to measure the average bubble diameter and the number of bubbles present at any time in the column. Several pictures were taken of the bubbles rising in the column and these pictures were enlarged to actual size. From the pictures, it was possible to measure bubble diameters and arrive at an average diameter. Knowing the diameter of the bubble, both the surface area and volume of the average bubble could be calculated. The number of bubbles was determined as follows.

The height of a column of a known volume (30 liters) of liquid was measured. The height of the liquid column was then remeasured under expanded conditions with gas bubbling through it. The liquid height was measured at various flow rates and was noted. The volume difference between the expanded and unexpanded column was equal to the volume of the gas bubbles in the liquid. Dividing this volume by the volume of the average bubble yielded the number of bubbles present.

Results - The test data is shown in Table 21. The diameter of the average bubble was measured to be 0.45 centimeters. The volume and surface area of an average bubble, therefore, were 0.0477 $cm^3$ and 0.636 $cm^2$ respectively. Values for the rate of carbon dioxide transfer, interfacial area, and the liquid film coefficient are shown in Table 21.

## Discussion of the Results

From Table 21 it may be seen that the efficiency of absorption of carbon dioxide from flue gas by the waste varied from 42 percent to 100 percent of the carbon dioxide present in the flue gas. The efficiency of the absorption was related in a general way to the pH of the waste, i.e., the higher the pH the higher the efficiency of absorption.

For design purposes, an efficiency of absorption of 50 percent is recommended. This recommendation is based on using a carbonation basin at least 8 ft deep as compared with 6 ft 7-in depth in the test column.

The time required to reduce the pH to about 9.5 was related to the total alkalinity and varied from about 2 minutes for an alkalinity of 900 mg/l to more than 20 minutes for an alkalinity of 6030 mg/l. The average alkalinity for the tannery effluent from the 1968 survey (Table 4) was about 2800 mg/l with hourly fluctuations between 0 and about 7500 mg/l. Equalization will be necessary and will iron out the fluctuations to an estimated range of between 1000 mg/l to 3500 mg/l on a slowly changing basis. Hence, a 20 minute contact period will be sufficient to permit adequate pH adjustment prior to secondary treatment.

Table 22 presents the computed rates of carbon dioxide transfer and the liquid film coefficients. The computed liquid film coefficients ranged from about 24 cm/hr to about 48 cm/hr. These values fall within the range of published data(14) indicating that no particular characteristic of the waste adversely effects the transfer of carbon dioxide from the flue gas to the waste.

## TABLE 21. TEST DATA - FLUE GAS UTILIZATION TESTS

| Flow Rate l/min | % $CO_2$ in Flue Gas | Carbonation Time (min) | pH of Waste | Alkalinity to pH 8.3 (mg/l as $CaCO_3$ | % $CO_2$ in Effluent Gas | % Utilization of $CO_2$ in Flue Gas |
|---|---|---|---|---|---|---|
| 5 | 11.4 | 0 | 10.8 | 525 | | |
| | | 1.0 | 10.7 | | 4.4 | 61 |
| | | 2.0 | 10.0 | | | |
| | | 2.5 | 9.7 | 360 | | |
| | | 3.0 | | | 6.0 | 47 |
| | | 3.5 | 9.3 | 250 | | |
| | | 4.5 | 8.9 | 130 | 3.4 | 70 |
| 5 | 11.2 | 0 | 12.2 | 6,030 | | |
| | | 1.0 | | | 0 | 100 |
| | | 5.0 | 12.0 | 5,520 | 0 | 100 |
| | | 15 | 11.8 | 3,700 | 0 | 100 |
| | | 20 | 12.0 | 3,030 | | |
| 10 | 11.4 | 0 | 11.4 | 660 | | |
| | | 1.0 | 11.2 | | | |
| | | 1.5 | 10.5 | | 5.4 | 52 |
| | | 2.0 | | 300 | | |
| | | 3.0 | 9.7 | | | |
| | | 3.5 | 9.0 | 135 | 6.6 | 42 |
| 15 | 11.4 | 0 | 11.5 | 900 | | |
| | | 1.5 | | | 3.0 | 73 |
| | | 2 | 11.2 | 560 | | |
| | | 3.5 | 9.6 | 225 | 4.6 | 60 |
| 25 | 11.4 | 0 | 11.2 | 900 | | |
| | | 0.5 | | | 5.8 | 49 |
| | | 1.0 | 10.3 | 620 | | |
| | | 2.0 | 9.45 | 475 | 4.2 | 63 |
| | | 2.5 | 9.1 | 325 | 4.0 | 65 |

## TABLE 22. RESULTS OF FLUE GAS UTILIZATION TESTS

| Gas Flow (l/min) | Rate of $CO_2$ Transfer dC/dt (mg/l/hr) | Surface Area of Bubbles/ Unit Volume ($cm^{-1}$) | $K_L$ (cm/hr) |
|---|---|---|---|
| 5 | 1,200 | 0.76 | 24.4 |
| 10 | 1,640 | 1.06 | 34.9 |
| 15 | 3,450 | 1.35 | 41.2 |
| 25 | 5,100 | 1.92 | 48.2 |

## CHLORINATION STUDIES

### General

In order to prevent the discharge of pathogenic organisms via the effluent from a waste treatment plant, the effluent of the treatment plant is chlorinated. Chlorine will kill pathogenic organisms in waste providing that the chlorine dosage and the period of chlorine contact is sufficient. The dosage and contact period are interrelated. Greater dosages of chlorine require lesser times of contact to effect a given percentage kill of organisms; with longer contact time, lesser amounts of chlorine are required. However, since the impurities in the waste will react with chlorine more rapidly than the chlorine will kill pathogenic organisms sufficient chlorine must always be added to satisfy this chlorine demand in addition to that necessary for disinfection.

Grab samples of the pilot plant effluent were collected from time to time to measure the chlorine demand of the effluent. The test procedures and results follow:

Procedure - Sodium hypochlorite solution was added in varying amounts to the sample of waste under test. The treated waste was set aside in the dark for a period of time after which the chlorine residual in the waste was measured. In some cases, the number of coliform organisms present in the wastes before chlorination and after the contact period were enumerated. The extent of reduction in the numbers of these organisms was used as a measure of the effectiveness of chlorination. The analytical procedures used for these tests are cited below:

> Chlorine - standardization of the chlorine solution (sodium hypochloride) and the analysis of the treated wastes for the chlorine residual were performed by the iodimetric method as described in "Standard Methods for the Examination of Water and Wastewater," using phenylarsene oxide solution and detecting the end point with starch solutions.
>
> Coliform organisms - Enumeration of coliform organisms was performed according to Standard Methods using the Millipore filter techniques.

Results - Figs. 29 and 30 show the relationship between chlorine dosage and chlorine residuals for tests on three different effluent samples.

Table 23 shows the range of coliform populations found in the tests of the pilot plant effluent. From Table 23 it may be seen that the number of coliforms in the samples ranged from 1,200,000 to 90,000 per 100 ml. The effectiveness of the chlorine was tested with chlorine doses ranging from 5 to 15 mg/l.

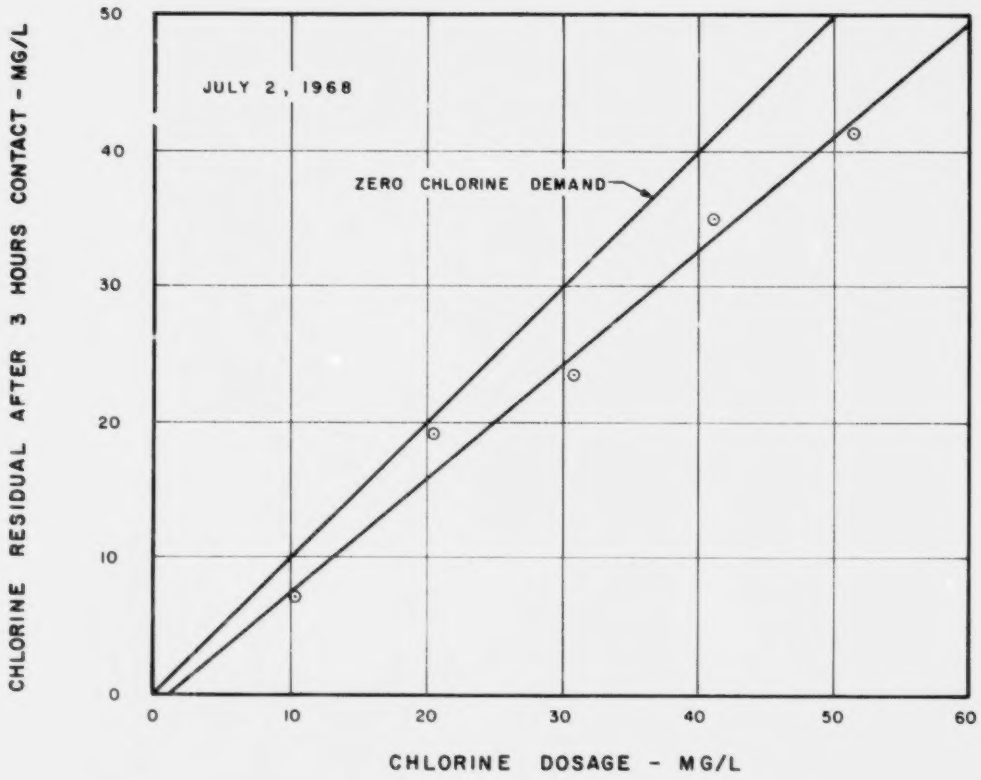


FIG. 29 CHLORINATION OF PILOT PLANT EFFLUENT

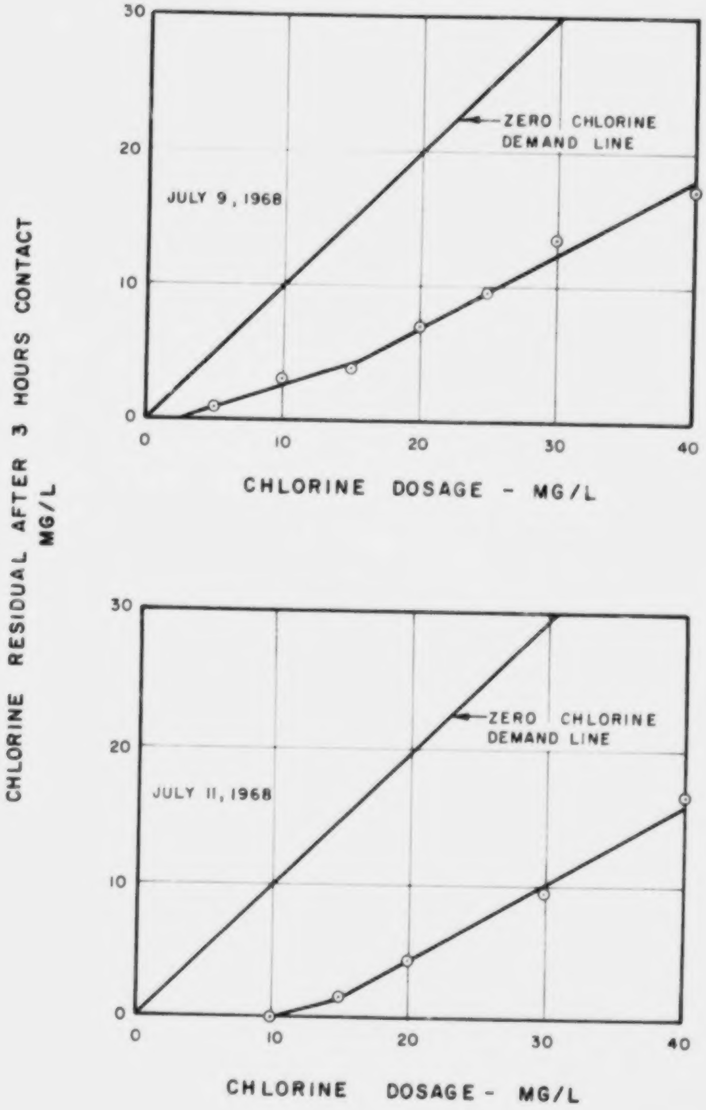


FIG. 30 CHLORINATION OF PILOT PLANT EFFLUENT

## TABLE 23. COLIFORM ANALYSES OF PILOT PLANT EFFLUENT

| Date | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Chlorine dose, mg/l | 0 | 5 | 10 | 10 | 15 |
| Contact time, min | 0 | 3 | 3 | 30 | 30 |
| | (Numbers of coliform bacteria per 100 ml of plant effluent) | | | | |
| June 21, 1968 | 152,000 | | | | |
| July 2, | 1,200,000 | 8,240 | 1,100 | | |
| July 9, | 312,000 | | | 320 | 35 |
| July 11, | 90,000 | | | | 36(1) |

(1) 8.2 mg/l chlorine residual after 30 minutes contact time, residual after 3 hrs, 1.8 mg/l.

In each test, the number of coliforms was reduced by more than 99.8 percent. In the test on July 12, 5 mg/l of chlorine reduced the number of coliforms present from 1,200,000 to 8,240 with a 3 minute contact time.

On the same sample, a 10 mg/l dosage of chlorine reduced the coliform count to 1,100 with a 3 minute contact time. On July 9, a sample containing 312,000 coliform bacteria per 100 ml was dosed with 10 mg/l of chlorine for 30 minutes and the coliform count was reduced to 320 per 100 ml. The same sample with a 15 mg/l dose of chlorine and a 30 minute contact period resulted in a reduction of the coliform count to 35 per 100 ml. A similar result was observed on July 11, in which test 15 mg/l dose of chlorine reduced the coliform count to 36 per 100 ml in 39 minutes. In this test, the chlorine residual was 8.2 mg/l after 30 minutes and 1.8 mg/l after three hours.

These tests indicate in general, that the effluent from the secondary sedimentation basin has a 30 minute chlorine demand of about 10 mg/l. The three hour chlorine demand increases slightly to between 13 and 16 mg/l. Furthermore, it appears that a 15 mg/l chlorine dose and a 30 minute contact period will result in a satisfactory reduction in the coliform concentration. The effluent will be suitable for discharge to the Little Androscoggin River. The discharge of an effluent containing less than 100 coliform bacteria per 100 ml should pose no serious health hazard downstream from the point of discharge.

# SULFIDE TOXICITY

## General

A major constituent of the tannery effluent is sulfide. Sulfides in water are known to be toxic to fish in the 1-10 mg/l range. The study described below was made to determine the toxicity of sulfide to the activated sludge.

Procedure - A solution of commercial grade sodium sulfide was prepared and fed to the aeration basin of the pilot plant. On April 2, 1968, 400 mg/l of sulfide was added for a period of two hours. During the periods April 2 to 3, and April 4 to 5, 5, 50 and 100 mg/l respectively of sulfide were added for 24-hour periods to the aeration basin. The dosages were based on the effluent carbonation basin flow of 2 gpm.

In addition to the tests described above which were conducted in the pilot plant, laboratory tests were conducted which yielded information concerning sulfide toxicity. These laboratory tests are described in the sections Sulfide Oxidation and Oxygen Uptake Studies - tests 5, 6 and 7.

The results of these various investigations are discussed below.

Results - The pilot plant tests showed little effect of the sulfide additions on the activated sludge. Addition of 400 mg/l of sulfide did cause a problem of excessive foaming in the aerator. However, after the sulfide feed was stopped and foaming had subsided, the activated sludge appeared to have suffered no damage. The ability of the activated sludge to cope with high sulfide dosages was indicated also in the laboratory tests.

During the oxygen uptake studies, it was shown that addition of up to 250 mg/l of sulfide caused a sharp increase in the rate of oxygen uptake (see Figs. 23 and 24). This indicates that the sulfide was easily utilized by the organisms of the activated sludge. Although the mechanisms by which the sulfide was utilized were not determined the sulfide oxidation tests showed that the micro-organisms were essential to the rapid conversion of sulfide to sulfate.

The overall average sulfide concentration determined in the 48-hour raw waste survey of April 9 to 11, was computed to be about 53 mg/l. The pilot plant tests showed that at best twice this concentration fed over a 24-hour period caused no problem. A dosage of 5 times the average concentration was easily handled by the organisms as evidenced by the oxygen uptake rate.

# CHROME TOXICITY

## General

Chromium, one of the heavy metals, will have a toxic effect on living organisms if it is absorbed in sufficient quantity. Since the activated sludge process is dependent upon the living organisms in the sludge for breakdown of the waste, and since the wastewater contains chromium, it was necessary to determine if the concentration of chromium in the waste might become enough to retard the biological action or kill the sludge organisms.

Procedure - A solution of basic chrome sulfate was added directly to the aeration basin continuously for four days. The rate of addition was held constant throughout each full day and was increased each day. Thus, on July 9, 10, 11, and 12 chromium was added at the rate of 40, 80, 120 and 160 mg/l respectively, based on the flow of 2 gpm of the carbonation basin effluent. These concentrations of chromium were in addition to the chromium derived from the tannery waste and already present in the carbonation basin effluent.

Results - There was no apparent detrimental effect on the action of the activated sludge due to the addition of chrome in the concentration used. The suspended and volatile suspended solids concentrations of the mixed liquor remained relatively constant. BOD removal in the aeration basin was good. No excess suspended solids were found to appear in the secondary settling basin effluent. Variations in each of these would have been expected if the chromium had reached toxic levels.

The effect of chromium on the rate of oxygen uptake was studied in Test 13 of the section Oxygen Uptake Tests. The plot (Fig. 27) of the results of this test shows no reduction in the rate of oxygen uptake with the addition of 100 mg/l of chromium.

Discussion - It has been demonstrated that the chromium concentration in the activated sludge basin influent can be maintained at less than 100 mg/l by means of primary settling. The toxicity level of chromium to the activated sludge appears to be considerably above this concentration. Therefore, chromium in the concentrations normally occurring in the tannery effluent should have no effect on the action of the activated sludge system.

# ACKNOWLEDGEMENTS

The investigation and studies reported herein were jointly carried out by the A.C. Lawrence Leather Company and Camp, Dresser & McKee, Consulting Engineers. Mr. Joseph Bassett was the Project Director; Dr. Robert H. Culver was Assistant Project Director; Mr. John C. Thompson was Project Engineer and Mr. Norton G. True was Resident Engineer.

The laboratory staff of the A.C. Lawrence Leather Company made the chromium analyses and the maintenance staff at the South Paris tannery performed the nonroutine maintenance, made necessary equipment installations, changes and repairs. The project was given full cooperation by the management and the research and development sections of the Company.

The advice and assistance of Mr. M.H. Battles, Director of Research for the Company, and Project Officer, Dr. Thomas A. Murphy of the Federal Water Pollution Control Administration, are hereby acknowledged.

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# APPENDIX

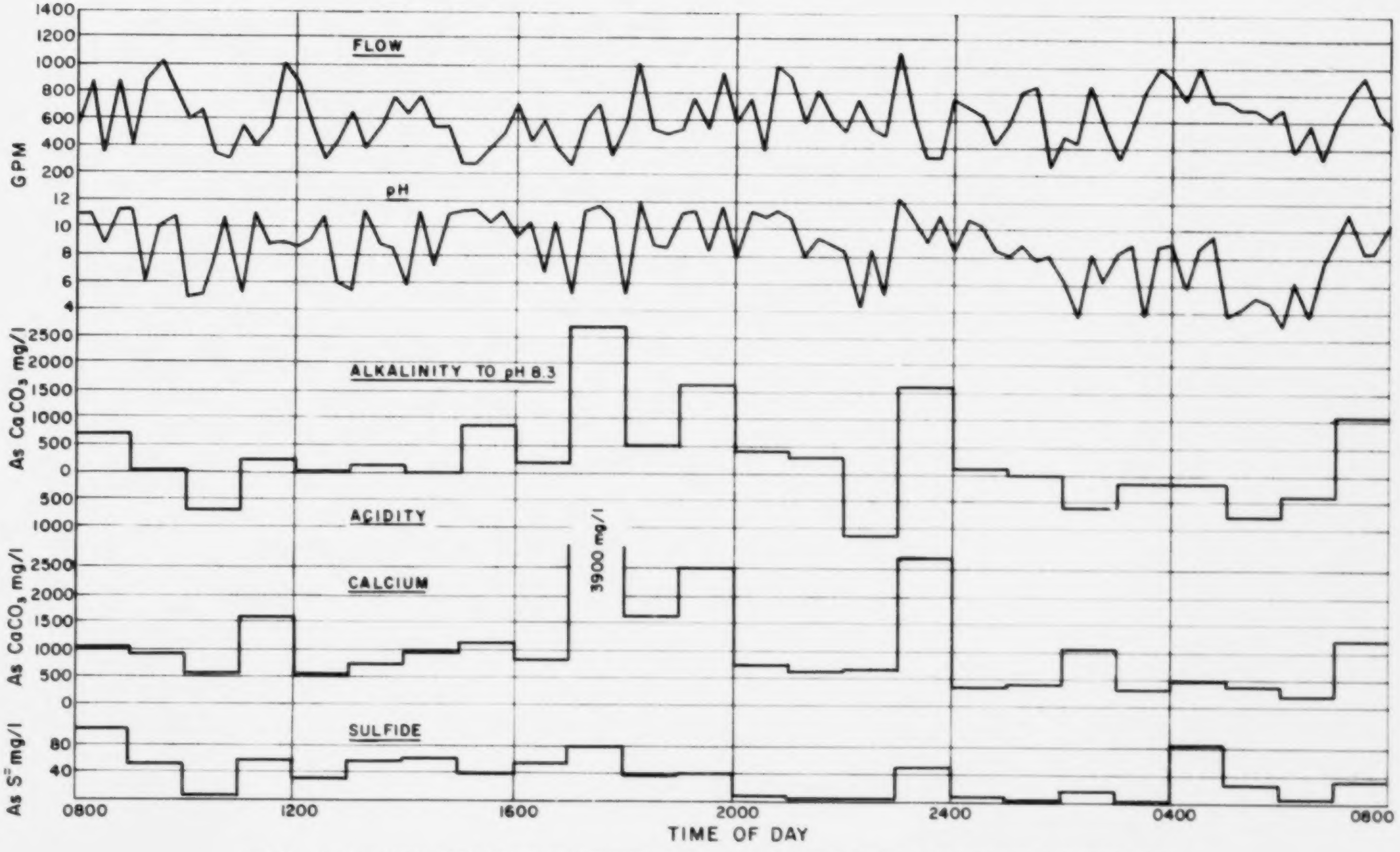

FIG. A-1 RAW WASTE SURVEY A.C. LAWRENCE LEATHER COMPANY
SOUTH PARIS, MAINE APRIL 9-10,1968

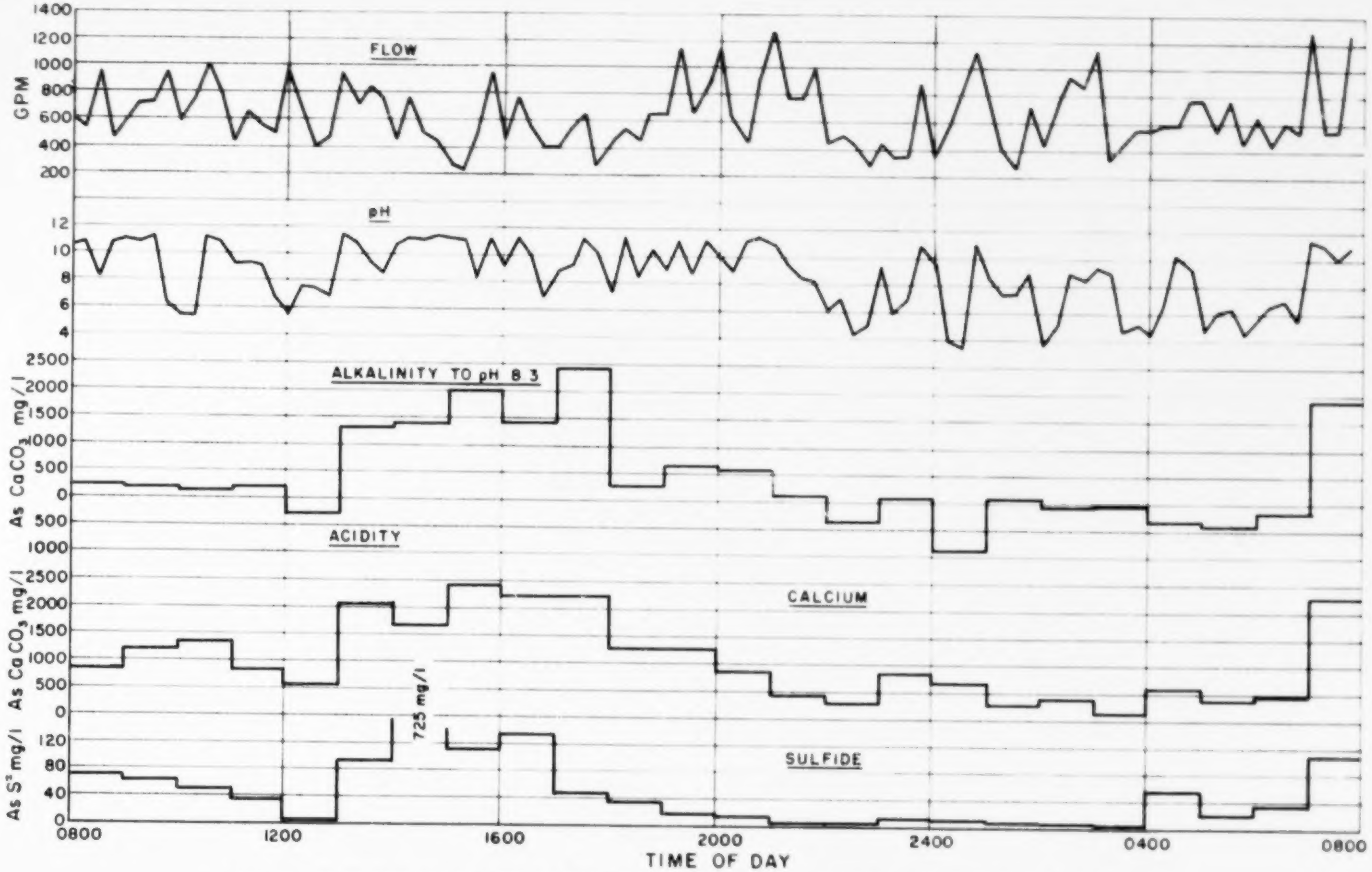

FIG. A-2 RAW WASTE SURVEY A.C. LAWRENCE LEATHER COMPANY
SOUTH PARIS, MAINE APRIL 10-11, 1968

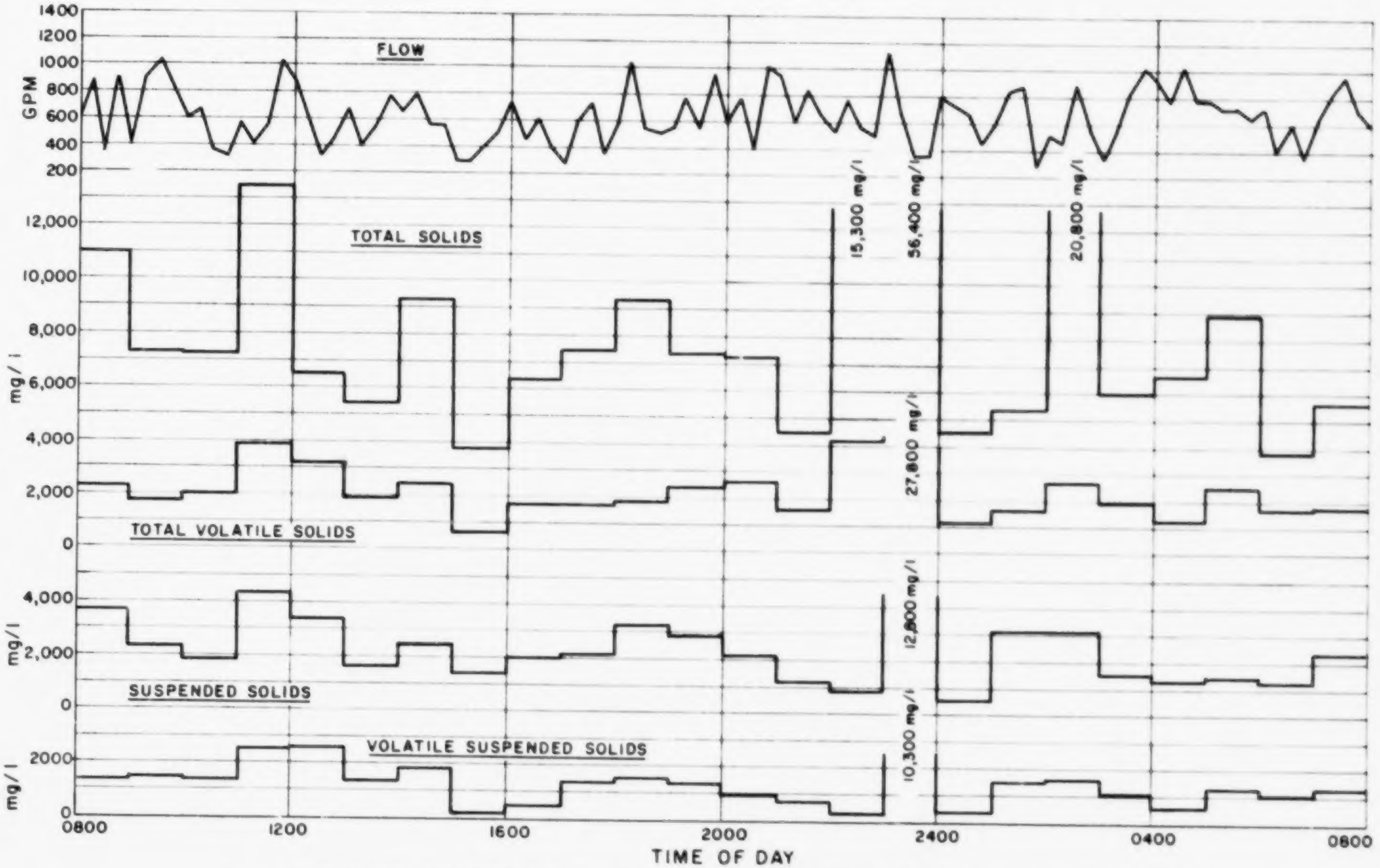

FIG. A-3 RAW WASTE SURVEY A.C. LAWRENCE LEATHER COMPANY
SOUTH PARIS, MAINE APRIL 9-10, 1968

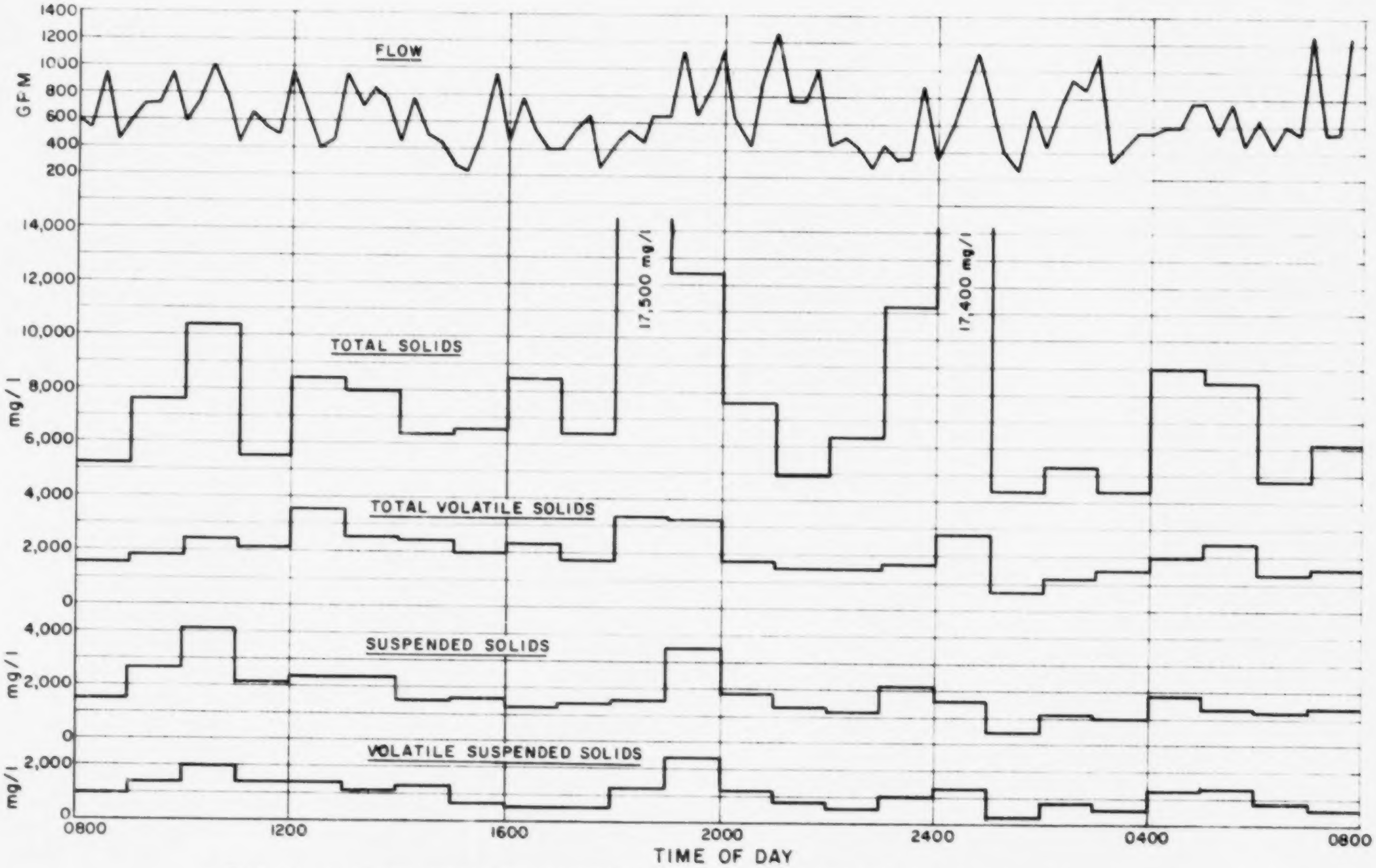

FIG. A-4 RAW WASTE SURVEY A.C. LAWRENCE LEATHER COMPANY
SOUTH PARIS, MAINE APRIL 10-11,1968

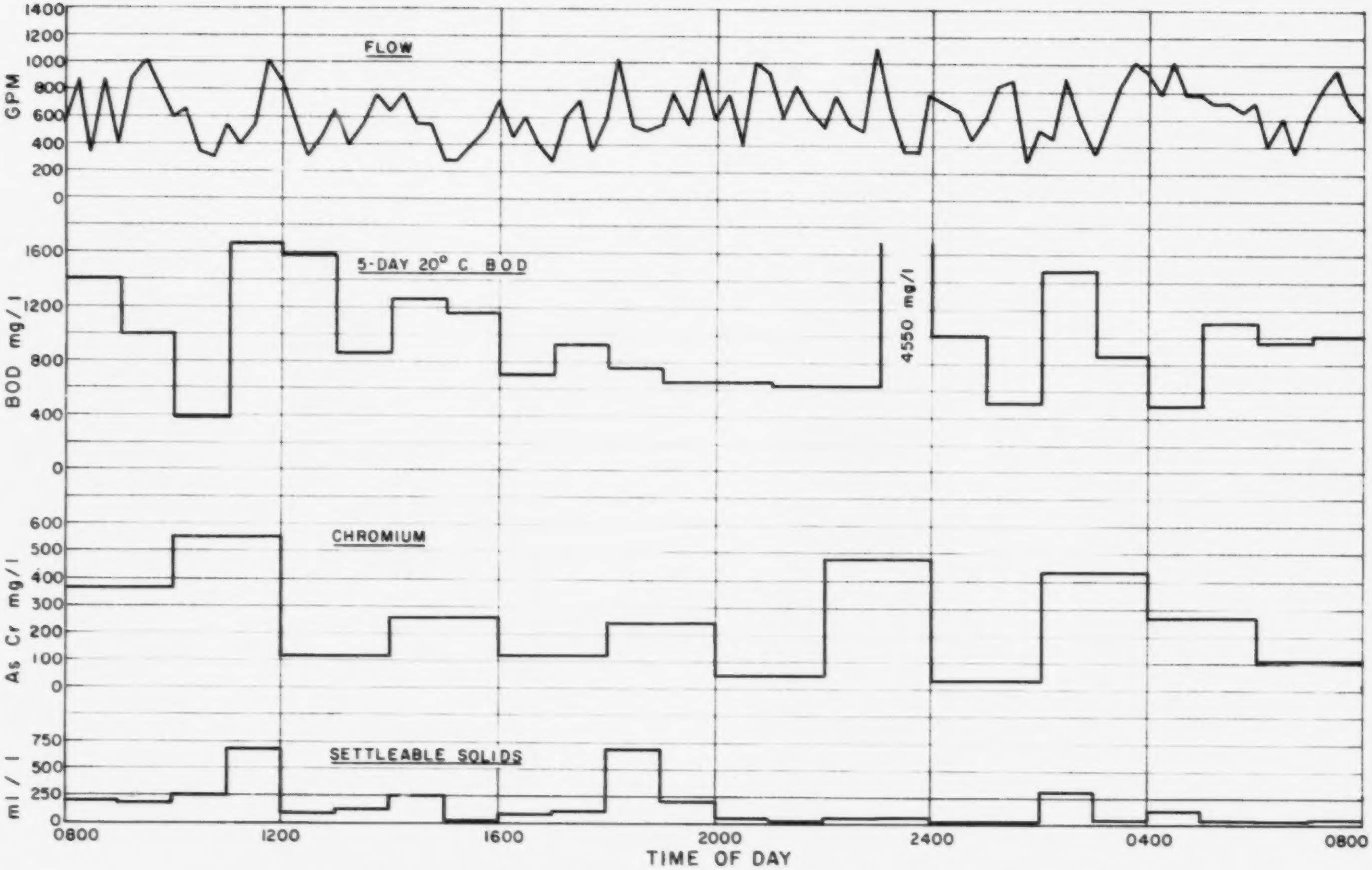

FIG. A-5 RAW WASTE SURVEY A.C. LAWRENCE LEATHER COMPANY
SOUTH PARIS, MAINE APRIL 9-10, 1968

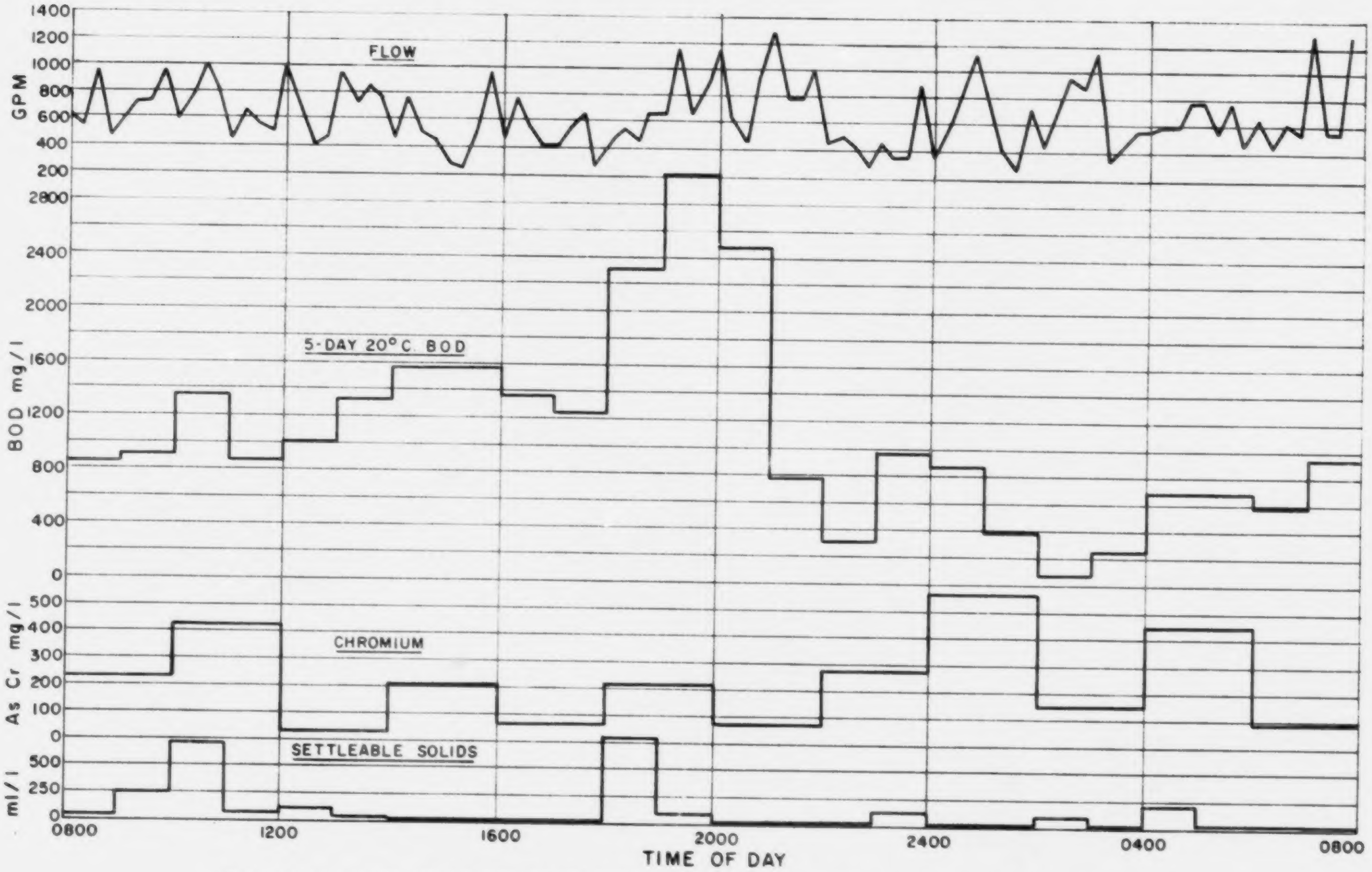

FIG. A-6 RAW WASTE SURVEY A.C. LAWRENCE LEATHER COMPANY
SOUTH PARIS, MAINE APRIL 10-11, 1968

TABLE A-7 PRIMARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

APRIL, 1968

| | | | | | INFLUENT | | | | | | | | | | | EFFLUENT | | | | | | | | | | | SLUDGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FLOWS, gpm | | | | | SOLIDS, mg/l | | | | | | | | | | SOLIDS, mg/l | | | | | | | | | | | | |
| | | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | | |
| Day of Month | Hours of Operation | Beam House | Tan House | Total | pH | Alkalinity to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, ml/l | BOD mg/l | Calcium mg/l CaCO₃ | pH | Alkalinity to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, ml/l | BOD mg/l | Calcium mg/l CaCO₃ | Volume Drawn, gals | Total Solids, mg/l | Total Vol. Solids, mg/l |
| 24 | 24 | 5 | 1.25 | 6.25 | 11.8 | 830 | | | | | | | 14 | 2,600 | 1,350 | 11.6 | 540 | | | | | | | 6 | 900 | 820 | 230 | | |
| 25 | 24 | 5 | 1.25 | 6.25 | 11.9 | 825 | 12,614 | 2,020 | 1,694 | 962 | 10,920 | 1,058 | 13 | 2,100 | 1,310 | 11.6 | 565 | 5,066 | 2,254 | 604 | 390 | 4,462 | 864 | 2 | 1,390 | 860 | 170 | 71,912 | 37,516 |
| 26 | 24 | 5 | 1.25 | 6.25 | 11.8 | 930 | 7,000 | 2,008 | 1,012 | 688 | 5,988 | 1,320 | 14 | 1,580 | 1,380 | 11.6 | 695 | 4,660 | 1,030 | 450 | 144 | 4,210 | 886 | 8 | 640 | 930 | 330 | 72,694 | 36,428 |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 24 | 5 | 1.25 | 6.25 | 11.6 | 1,365 | 6,308 | 2,004 | 1,238 | 1,014 | 5,070 | 990 | 22 | 1,130 | 1,740 | 11.4 | 515 | 5,656 | 978 | 502 | 122 | 5,154 | 856 | 15 | 690 | 1,270 | 120 | 50,048 | 24,154 |
| 30 | 24 | 5 | 1.25 | 6.25 | 11.5 | 815 | 4,710 | 1,076 | 1,116 | 588 | 3,594 | 488 | 18 | 810 | 1,660 | 11.4 | 625 | 4,410 | 408 | 492 | 0 | 3,918 | 452 | 4 | 620 | 1,270 | 180 | 58,738 | 24,294 |

TABLE A-? PRIMARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

MAY, 19??

INFLUENT

EFFLUENT

SLUDGE

FLOW

SOLIDS, mg/l

TOTAL

SUSPENDED

DISSOLVED

[illegible]

## TABLE A-3. PRIMARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES
## JUNE

| | | FLOWS gpm | | | INFLUENT | | | | | | EFFLUENT | | | | | SLUDGE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Day of Month | Hours of Operation | Beam House | Tan House | Total | Temperature °F | pH | Alkalinity to pH 8.3 | Settleable Solids, ml/l | BOD mg/l | Sulfide mg/l | pH | Alkalinity to pH 8.3 | Settleable Solids, ml/l | BOD mg/l | Sulfide mg/l | Volume Drawn, gals | Sulfide mg/l |
| 1 | | Water | | | | | | | | | | | | | | 20 | |
| 2 | | Water | | | 66 | | | | | | | | | | | | |
| 3 | 24 | 4.5 | 1.5 | 6.0 | 67 | 11.0 | 310 | 10.0 | 855 | | 11.1 | 330 | 1.5 | 615 | | 65 | |
| 4 | 24 | 4.5 | 1.5 | 6.0 | 72 | 11.6 | 730 | 11.5 | 1,225 | | 11.4 | 450 | 1.4 | 795 | | 111 | |
| 5 | 24 | 4.5 | 0.75 | 5.25 | 68 | 11.7 | 730 | 18.0 | 1,150 | | 11.6 | 610 | 2.0 | 1,100 | | 120 | |
| 6 | 24 | 4.5 | 0.75 | 5.25 | 67 | 11.5 | 945 | 14.0 | 1,125 | | 10.9 | 415 | 1.0 | 975 | | 112 | |
| 7 | 24 | 4.5 | 1.5 | 6.0 | 64 | 11.3 | 655 | 17.0 | 1,440 | | 11.4 | 675 | 3.0 | 1,410 | | 166 | |
| 8 | | Water | | | | | | | | | | | | | | | |
| 9 | | Water | | | 66 | | | | | | | | | | | | |
| 10 | 24 | 4.5 | 1.5 | 6.0 | 70 | 10.0 | 180 | 8.0 | 1,170 | | 11.1 | 325 | 5.0 | 1,030 | | 150 | |
| 11 | 24 | 4.5 | 0.75 | 5.25 | 67 | 11.3 | 635 | 12.0 | 1,260 | | 10.9 | 285 | 4.0 | 1,050 | | 170 | |
| 12 | 24 | 4.5 | 1.0 | 5.5 | 70 | 12.2 | 1,440 | 11.0 | 1,500 | | 12.0 | 830 | 1.0 | 970 | | 160 | |
| 13 | 24 | 4.5 | 0.75 | 5.25 | 65 | 12.2 | 1,020 | 5.0 | 995 | | 12.0 | 580 | 0.5 | 780 | | 172 | |
| 14 | 24 | 4.5 | 1.0 | 5.5 | | 11.8 | 920 | 18.0 | 1,000 | | 11.8 | 770 | 0.2 | 720 | | 136 | |
| 15 | | Water | | | | | | | | | | | | | | | |
| 16 | | Water | | | 66 | | | | | | | | | | | | |
| 17 | 24 | 4.5 | 1.0 | 5.5 | 66 | 11.4 | 490 | 5.2 | | 64 | 11.6 | 630 | 0.9 | | 100 | 110 | 86 |
| 18 | 24 | 4.5 | 1.0 | 5.5 | 70 | 11.1 | 370 | 5.8 | | 49 | 11.5 | 620 | 0.3 | | 61 | 137 | 68 |
| 19 | 24 | 4.5 | 1.0 | 5.5 | 62 | 11.6 | 800 | 12.0 | | 46 | 11.7 | 780 | 1.5 | | 46 | 169 | 102 |
| 20 | 24 | 4.5 | 0.75 | 5.25 | 65 | 11.4 | 520 | 5.0 | | 70 | 11.4 | 380 | 0.6 | | 52 | 118 | 99 |
| 21 | 24 | 4.5 | 1.0 | 5.5 | | 10.8 | 270 | 11.0 | | 39 | 11.3 | 490 | 0.7 | | 39 | 150 | 82 |
| 22 | | Water | | | | | | | | | | | | | | | |
| 23 | | Water | | | | | | | | | | | | | | | |
| 24 | 24 | 4.5 | 1.5 | 6.0 | | 11.4 | 735 | 10.0 | | | 11.1 | 375 | 1.2 | | | 108 | |
| 25 | 24 | 4.5 | 1.5 | 6.0 | 69 | 10.8 | 275 | 15.0 | | | 11.0 | 300 | 2.5 | | | 136 | |
| 26 | 24 | 4.5 | 1.0 | 5.5 | 68 | 11.2 | 420 | 10.0 | | | 11.2 | 435 | 0.8 | | | 150 | |
| 27 | 24 | 4.5 | 0.75 | 5.25 | 66 | 11.7 | 730 | 8.0 | | | 11.3 | 315 | 0.5 | | | 141 | |
| 28 | 24 | 4.5 | 1.0 | 5.5 | 64 | 11.4 | 640 | 20.0 | | | 11.5 | 750 | 1.3 | | | 185 | |
| 29 | | Water | | | | | | | | | | | | | | | |
| 30 | | Water | | | | | | | | | | | | | | | |

## TABLE A-4. PRIMARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

## JULY, 1968

| Day of Month | Hours of Operation | FLOWS gpm |  |  | INFLUENT |  |  |  | EFFLUENT |  |  | Sludge Volume Drawn, gals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Beam House | Tan House | Total | Temperature °F | pH | Alkalinity to pH 8.3 | Settleable Solids, ml/l | pH | Alkalinity to pH 8.3 | Settleable Solids, ml/l |  |
| 1 | 24 | 4.5 | 1.5 | 6.0 |  | 11.6 | 950 | 28.0 | 11.4 | 470 | 0.6 | 79 |
| 2 | 24 | 4.5 | 1.5 | 6.0 | 80 | 11.3 | 450 | 7.4 | 11.3 | 450 | 0.7 | 141 |
| 3 | 24 | 4.5 | 1.0 | 5.5 | 75 | 11.4 | 415 | 5.0 | 11.5 | 595 | 2.5 | 120 |
| 4 |  |  |  |  |  |  |  |  |  |  |  |  |
| 5 | 24 | 4.5 | 1.0 | 5.5 | 73 | 11.7 | 715 | 6.0 | 11.5 | 660 | 0.5 | 90 |
| 6 |  |  |  |  |  |  |  |  |  |  |  |  |
| 7 |  |  |  |  |  |  |  |  |  |  |  |  |
| 8 | 24 | 4.5 | 1.0 | 5.5 |  |  |  |  |  |  |  | 80 |
| 9 | 24 | 4.5 | 1.0 | 5.5 |  | 11.4 | 820 | 15.0 | 11.4 | 675 | 2.5 | 114 |
| 10 | 24 | 4.5 | 1.0 | 5.5 | 68 | 11.6 | 1,170 | 7.5 | 11.4 | 605 | 0.3 | 77 |
| 11 | 24 | 4.5 | 1.0 | 5.5 |  | 11.5 | 1,340 | 14.0 | 11.3 | 665 | 0.7 | 150 |
| 12 | 12 | 4.5 | 1.0 | 5.5 |  |  |  |  |  |  |  | 50 |

TABLE A-[illegible] CARBONATION BASIN OPERATION AND ANALYSES
OF COMPOSITE SAMPLES

JANUARY, 1968

| | | | | | INFLUENT | | | | | | | | | | EFFLUENT | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SOLIDS, mg/l | | | | | | | | | | SOLIDS, mg/l | | | | | | | | | | |
| | | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | |
| Day of Month | Hours of Operation | Beam House Flow, gpm | Tan House Flow, gpm | Total Flow, gpm | pH | Alkalinity to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, ml/l | BOD mg/l | pH | Alkalinity to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, ml/l | BOD mg/l | Volume Drawn, gals | Total Solids, mg/l | Total Vol Solids, mg/l |
| 5 | 8 | 3 | 2 | 5 | 8.7 | 33 | | | | | | | 240 | | 7.6 | 290 | | | | | | | 140 | | 8 | | |
| 6 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | 2.5 | 3 | 2 | 5 | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | 5 | 3 | 2 | 5 | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | 8 | 3 | 2 | 5 | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | 0.5 | 4 | 2 | 6 | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | 6 | 6 | 2 | 8 | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | 2.5 | 6 | 2 | 8 | | | | | | | | | | | | | | | | | | | | | 62 | (11,704 | 9,554 |
| 17 | 0 | | | | | | | | | | | | | | | | | | | | | | | | 40 | ( | |
| 18 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 2 | 6 | 2 | 8 | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | 14.5 | 4 | 1.75 | 5.75 | 9.5 | 255 | 9,642 | 1,928 | 2,190 | 1,040 | 7,452 | 888 | 30 | 1,105 | 10.7 | 590 | 10,024 | 1,846 | 2,076 | 880 | 7,948 | 966 | 130 | 820 | 32 | 37,252 | 16,340 |
| 23 | 19 | 4 | 1.75 | 5.75 | 11.3 | 455 | 9,360 | 2,872 | 1,076 | 1,290 | 6,284 | 1,582 | 30 | | 10.2 | 265 | 8,028 | 1,206 | | | | | 10 | | 53 | 45,112 | 19,952 |
| 24 | 7 | 4 | 2.3 | 6.3 | 10.8 | 630 | | | | | | | 240 | | 11.8 | 895 | | | | | | | 12 | | 16 | | |
| 25 | 12.5 | 4 | 2.3 | 6.3 | | | | | | | | | | | | | | | | | | | | | 10 | | |
| 26 | 2 | 4 | 1.75 | 5.75 | 9.4 | 285 | | | | | | | 370 | | 8.8 | 90 | | | | | | | 170 | | | | |
| 27 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | 0 | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | 4.5 | | | | 9.4 | 395 | | | | | | | 420 | | | | | | | | | | | | 40 | | |
| 29 | 7 | 4 | 1.75 | 5.75 | | | | | | | | | | | 9.7 | | | | | | | | 280 | | 42 | | |
| 30 | 13 | 4 | 1.75 | 5.75 | 11.3 | | 9,014 | 1,674 | 2,550 | 1,250 | 6,464 | 624 | 215 | 1,200 | 11.4 | 840 | 7,662 | 1,640 | 2,122 | 1,034 | 5,540 | 606 | 85 | 900 | 182 | 43,985 | 21,098 |
| 31 | 23 | 4 | 1.75 | 5.75 | 11.7 | 1,220 | | | | | | | 30 | 1,050 | 11.4 | 1,075 | | | | | | | 0.5 | 650 | 144 | | |

TABLE A-5 CARBONATION BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

FEBRUARY, 1968

| | | | | | INFLUENT | | | | | | | | | | EFFLUENT | | | | | | | | | | SLUDGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | SOLIDS, mg/l | | | | | | | | | | SOLIDS, mg/l | | | | | | | | | | |
| | | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | |
| Day of Month | Hours of Operation | Beam House Flow, gpm | Tan House Flow, gpm | Total Flow, gpm | pH | Alkalinity, to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, ml/l | BOD mg/l | pH | Alkalinity, to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, | BOD mg/l | Volume Drawn, gals | Total Solids, mg/l | Total Vol. Solids, mg/l |
| 1 | 11 | 4 | 1.75 | 5.75 | 9.8 | 215 | 8,160 | 1,840 | 2,372 | 1,260 | 5,788 | 580 | 215 | 1,680 | 10.8 | 320 | 8,772 | 2,046 | 2,370 | 1,220 | 6,402 | 826 | 100 | 1,286 | 94 | 43,250 | 22,644 |
| 2 | 2 | 4 | 1.75 | 5.75 | 11.0 | 450 | | | | | | | 120 | | 10.9 | 435 | | | | | | | 150 | | 132 | | |
| 2 | 7 | 4 | 2.0 | 6.0 | | | | | | | | | | | | | | | | | | | ( | | 30 | | |
| 3 | 2 | 4 | 2.3 | 6.3 | 10.2 | 590 | 10,178 | 2,796 | 2,634 | 1,304 | 7,544 | 1,492 | 280 | 302 | 10.8 | 495 | (10,852 | 3,280 | 3,032 | 2,132 | 7,820 | 1,148 | 240 | 670 | - | 37,272 | 18,700 |
| 3 | 18 | 4 | 1.75 | 5.75 | | | | | | | | | | | | | ( | | | | | | | | 120 | | |
| 6 | 17 | 4 | 1.75 | 5.75 | | | | | | | | | | 1,020 | | | | | | | | | | 960 | 192 | | |
| 7 | 16 | 4 | 1.75 | 5.75 | 11.1 | 465 | | | | | | | 80 | | 11.2 | 410 | | | | | | | 2 | | 90 | | |
| 8 | 13 | 4 | 1.4 | 5.4 | | | | | | | | | | | | | | | | | | | | | 58 | | |
| 9 | 7 | 4 | 0 | 4.0 | | | | | | | | | | | | | | | | | | | | | 54 | | |
| 9 | 12 | 4 | 1.0 | 5.0 | | | | | | | | | | | | | | | | | | | | | 38 | | |
| 10 | 5.5 | 4 | 0 | 4 | | | | | | | | | | | | | | | | | | | | | 16 | | |
| 12 | 7 | 4 | 0 | 4 | 11.0 | 440 | | | | | | | Trace | | 8.2 | | | | | | | | (0 | | 27 | | |
| 12 | 11 | 4 | 1.0 | 5 | | | | | | | | | | | | | | | | | | | ( | | 68 | | |
| 13 | 14 | 4 | 0 | 4 | | | | | | | | | | | 8.7 | 55 | | | | | | | (1 | | 98 | | |
| 13 | 7 | 4 | 1.0 | 5 | | | | | | | | | | | | | | | | | | | ( | | 64 | | |
| 14 | 12 | 4 | 0 | 4 | (11.0 | 695 | | | | | | | 25 | | 9.4 | 180 | | | | | | | (0 | | 40 | | |
| 14 | 12 | 4 | 1.0 | 5 | ( | | | | | | | | | | | | | | | | | | ( | | 148 | | |
| 15 | 24 | 4 | 0 | 4 | | | | | | | | | | | 9.6 | 220 | | | | | | | 2 | | 132 | | |
| 16 | 3 | 4 | 0 | 4 | (12.1 | 875 | | | | | | | | 1,305 | 11.8 | 385 | | | | | | | (1.5 | 885 | 60 | | |
| 16 | 18 | 4 | 1.0 | 5 | ( | | | | | | | | | | | | | | | | | | ( | | 56 | | |
| 17 | 1 | 4 | 1.0 | 5 | | | | | | | | | | | | | | | | | | | | | - | | |
| 18 | 4 | 4 | 1.0 | 5 | 10.7 | 465 | 7,356 | 1,120 | | | | | 28 | 828 | 9.8 | 180 | 7,748 | 944 | | | | | | 837 | 92 | 68,848 | 33,592 |
| 19 | 13 | 4 | 0 | 4 | | | | | | | | | | | | | | | | | | | | | 36 | | |
| 19 | 9 | 4 | 1.0 | 5 | | | | | | | | | | | | | | | | | | | | | 164 | | |
| 20 | 16 | 4 | 0 | 4 | 10.4 | 685 | | | | | | | 2.5 | | 9.4 | 100 | | | | | | | (Trace | | 104 | | |
| 20 | 8 | 4 | 1.0 | 5 | ( | | | | | | | | | | | | | | | | | | ( | | 136 | | |
| 21 | 11 | 4 | 0 | 4 | (10.6 | | 3,628 | 1,100 | | | | | | 559 | | | (6,112 | 1,172 | | | | | | 602 | 84 | (69,812 | 35,304 |
| 21 | 13 | 8 | 2.0 | 10 | ( | | | | | | | | | | | | ( | | | | | | | | 189 | ( | |
| 22 | 24 | 2 | 0 | 2 | 11.8 | 1,120 | | | | | | | | | 8.9 | 80 | | | | | | | | | 136 | | |
| 23 | 7.5 | 2 | 0 | 2 | 11.4 | 1,450 | | | | | | | | | 10.6 | 350 | | | | | | | | | 8 | | |
| 23 | 8 | 2 | 1.0 | 3 | | | | | | | | | | | | | | | | | | | | | 46 | | |
| 26 | 15 | 3 | 1.6 | 4.6 | 9.1 | 185 | | | | | | | | | 10.0 | 395 | | | | | | | | | 432 | | |
| 27 | 16 | 4 | 1.0 | 5.0 | 10.6 | 420 | 6,964 | 1,436 | 1,280 | 360 | 5,684 | 1,076 | | | 10.1 | 320 | (6,152 | 628 | 544 | 16 | 5,608 | 612 | | | 256 | (39,172 | 18,512 |
| 27 | 2 | 4 | 0 | 4 | | | | | | | | | | | | | ( | | | | | | | | 8 | ( | |
| 28 | 4 | 8 | 0 | 8 | 11.2 | 795 | 6,160 | 1,628 | 1,160 | 392 | 5,000 | 1,036 | 14 | | 11.1 | 605 | (7,568 | 1,408 | 580 | 312 | 6,988 | 1,096 | 3 | | 24 | (43,800 | 21,500 |
| 28 | 15 | 8 | 2.0 | 10 | ( | | | | | | | | | | | | | | | | | | | | 634 | ( | |
| 29 | 14 | 8 | 2.0 | 10 | 10.9 | 582 | 6,072 | 1,216 | 920 | 572 | 5,152 | 644 | | | 10.6 | 575 | 6,096 | 920 | 584 | 248 | 5,512 | 672 | | | 80 | 34,108 | 23,964 |

TABLE A- CARBONATION BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

MARCH 1968

INFLUENT

| Day | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | pH | Alkalinity | SOLIDS mg/l TOTAL Total | TOTAL Vol | SUSPENDED Total | SUSPENDED Vol | DISSOLVED Total | DISSOLVED Vol | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | 24 | [illegible] | [illegible] | [illegible] | | | 12.[illegible] | [illegible] | | | | | | | | | | | |
| [illegible] | 24 | | Water | | [illegible] | | | | | | | | | | | | | | |
| [illegible] | 24 | | Water | | [illegible] | | | | | | | | | | | | | | |
| 4 | 24 | 8 | [illegible] | [illegible] | | | 11.[illegible] | 4[illegible] | [illegible] | 724 | 2,[illegible] | 440 | 5,876 | 284 | | [illegible] | | | |
| [illegible] | 24 | 8 | [illegible] | [illegible] | | | [illegible] | 440 | | | | | | | 23 | | | | |
| [illegible] | 24 | 8 | [illegible] | [illegible] | | | [illegible] | 340 | | | | | | | 74 | | | | |
| [illegible] | 24 | 8 | [illegible] | [illegible] | | 56 | [illegible] | 320 | | | | | | | [illegible] | | | | |
| [illegible] | 24 | 4 | [illegible] | [illegible] | | 72 | [illegible] | 4[illegible] | 3,872 | [illegible] | 1,2[illegible] | 780 | 2,[illegible] | [illegible] | 80 | | | | |
| [illegible] | 24 | | Water | | [illegible] | | | | | | | | | | | | | | |
| [illegible] | 7 | 4 | [illegible] | | [illegible] | | | | | | | | | | | | | | |
| [illegible] | 24 | 4 | [illegible] | [illegible] | | [illegible] | [illegible] | [illegible] | [illegible] | 736 | 1,424 | 876 | [illegible] | 920 | 8 | 1,500 | | | |
| [illegible] | 24 | [illegible] | | | | 56 | [illegible] | [illegible] | 5,44[illegible] | [illegible] | 880 | 4[illegible] | 4,560 | 796 | [illegible] | 1,120 | | | |
| [illegible] | 24 | 8 | | | [illegible] | 8 | [illegible] | 720 | [illegible] | [illegible] | 1,720 | 1,128 | 4,[illegible] | 1,236 | 12 | 1,200 | | | |
| 14 | 24 | [illegible] | [illegible] | [illegible] | 4.2 | 56 | 11.6 | 620 | [illegible] | 1,476 | 4,416 | 1,388 | 1,300 | 88 | 12 | 840 | | | |
| [illegible] | 24 | 2 | [illegible] | [illegible] | 4.2 | | 11.2 | 4[illegible] | | | | | | | [illegible] | | | | |
| 16 | 48 | | Water | | 6 | | | | | | | | | | | | | | |
| [illegible] | 2 | | Water | [illegible] | 3 | [illegible] | | | | | | | | | | | | | |
| 18 | 24 | 12 | [illegible] | [illegible] | 12 | 56 | 11.4 | 430 | | | | | | | 5.0 | | | | |
| [illegible] | 24 | 12 | [illegible] | [illegible] | 12 | 56 | 11.5 | 480 | | | | | | | 10 | 1,470 | | | |
| [illegible] | 24 | [illegible] | [illegible] | [illegible] | 12 | 56 | 11.3 | 380 | | | | | | | | 28 | | | |
| [illegible] | 24 | [illegible] | [illegible] | [illegible] | 7 | 56 | 12.0 | 480 | | | | | | | [illegible] | [illegible] | | | |
| [illegible] | 24 | [illegible] | [illegible] | [illegible] | [illegible] | 72 | 11.6 | 440 | 5,316 | 1,436 | 1,068 | 700 | 3,968 | 736 | 16 | [illegible] | [illegible] | | |
| [illegible] | 24 | | Water | | [illegible] | | | | | | | | | | | | | | |
| 24 | 24 | | Water | | [illegible] | | | | | | | | | | | | | | |
| [illegible] | [illegible] | | Water | | [illegible] | | | | 11,904 | 1,384 | 1,260 | 928 | 4,644 | 416 | | | 42 | | |
| [illegible] | 24 | [illegible] | | | 6 | | 12.9 | 4[illegible] | | | | | | | 12 | | | | |
| 26 | 24 | [illegible] | | | 6 | [illegible] | 11.6 | [illegible] | [illegible] | 892 | 444 | 280 | 3,868 | 612 | 8 | 810 | 1,030 | | |
| [illegible] | 24 | 4 | | [illegible] | | | 11.6 | 6[illegible] | 5,4[illegible] | [illegible] | 1,036 | 660 | 4,366 | 612 | 8 | 787 | 1,170 | 187 | |
| 28 | 24 | 4 | | [illegible] | | | 11.2 | 470 | 5,687 | 1,368 | 1,2[illegible] | 804 | 4,624 | 884 | 8 | [illegible] | 880 | 131 | |
| [illegible] | 24 | 4 | | [illegible] | | 56 | 11.2 | 420 | 6,[illegible] | [illegible] | 1,442 | 806 | [illegible] | 564 | [illegible] | 1,810 | 1,890 | 216 | 80 |
| 30 | 24 | | Water | | [illegible] | | | | | | | | | | | | | | |
| 31 | 24 | | Water | | [illegible] | | | | | | | | | | | | | | |

EFFLUENT / SLUDGE

| Day | pH | Alkalinity mg/l | SOLIDS mg/l TOTAL Total | TOTAL Vol | SUSPENDED Total | SUSPENDED Vol | DISSOLVED Total | DISSOLVED Vol | Sulfide mg/l | BOD mg/l | Calcium mg/l CaCO₃ | Sulfate mg/l | Chromium mg/l | Volume Drawn gal | Solids mg/l | Volatile Solids mg/l | Chromium mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [illegible] | 9.6 | [illegible] | | | | | | | | | | | | 280 | | | |
| [illegible] | | | | | | | | | | | | | | 16 | | | |
| [illegible] | | | | | | | | | | | | | | | | | |
| 4 | 11.[illegible] | [illegible] | 6,440 | [illegible] | [illegible] | 228 | [illegible] | 836 | | 612 | | | | 210 | 43,996 | 21,236 | |
| [illegible] | [illegible] | 300 | | | | | | | [illegible] | | | | | 364 | | | |
| [illegible] | 11.[illegible] | 4[illegible] | | | | | | | 4 | | | | | 108 | | | |
| [illegible] | 10.[illegible] | 260 | | | | | | | [illegible] | | | | | 232 | | | |
| [illegible] | 10.8 | [illegible] | [illegible] | [illegible] | 644 | [illegible] | [illegible] | 428 | [illegible] | | | | | 374 | 41,264 | 21,988 | |
| [illegible] | | | | | | | | | | | | | | 108 | | | |
| [illegible] | | | | | | | | | | | | | | 38<br>108 | | | |
| [illegible] | 11.[illegible] | 340 | [illegible] | [illegible] | 628 | [illegible] | 4,644 | 1,0[illegible] | 1.[illegible] | 8[illegible] | | | | 360 | 28,760 | 12,492 | |
| [illegible] | 10.8 | 260 | 4,860 | 1,048 | 312 | 196 | 4,[illegible] | [illegible] | [illegible] | 1,[illegible] | | | | 404 | 32,420 | 8,468 | |
| [illegible] | 10.4 | 190 | 4,996 | 1,308 | 468 | [illegible] | 4,528 | 1,236 | 2 | 1,150 | | | | 710 | 27,656 | 11,544 | |
| 14 | 11.[illegible] | 610 | [illegible] | 1,068 | 392 | 380 | 1,220 | 888 | [illegible] | 76[illegible] | | | | 136 | 36,400 | 35,116 | |
| [illegible] | 10.9 | 240 | | | | | | | Trace | | | | | 300 | | | |
| 16 | | | | | | | | | | | | | | 80 | | | |
| [illegible] | | | | | | | | | | | | | | 32 | | | |
| 18 | 11.2 | 400 | | | | | | | 3.0 | | | | | 180 | | | |
| [illegible] | 11.4 | 340 | | | | | | | 5 | 1,060 | | | | 467 | | | |
| [illegible] | 11.6 | [illegible] | | | | | | | 6 | 1,110 | | | | 376 | | | |
| [illegible] | 11.8 | 120 | | | | | | | Trace | 1,[illegible] | | | | 370 | | | |
| [illegible] | 11.4 | 270 | 5,188 | 1,028 | [illegible] | 200 | 4,612 | 828 | Trace | 540 | 430 | | | 376 | | | |
| [illegible] | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | |
| [illegible] | | | 4,420 | 848 | 316 | [illegible] | 4,504 | [illegible] | | | [illegible] | | | | | | |
| [illegible] | 11.3 | 310 | [illegible] | | | | | | [illegible] | | | | | 260 | | | |
| 26 | 10.[illegible] | 325 | [illegible] | 790 | 340 | 236 | [illegible] | [illegible] | Trace | 612 | 836 | | | 264 | 30,032 | [illegible] | |
| [illegible] | 10.[illegible] | 250 | [illegible] | 804 | 128 | 366 | [illegible] | 480 | Trace | [illegible] | 1,230 | 121 | | 456 | 75,480 | 17,166 | |
| 28 | 9.3 | 160 | [illegible] | 890 | 396 | 116 | [illegible] | [illegible] | Trace | 92[illegible] | 590 | 131 | | 346 | 64,[illegible] | 26,164 | |
| [illegible] | 10.4 | [illegible] | [illegible] | 930 | 636 | [illegible] | [illegible] | [illegible] | [illegible] | 1,39[illegible] | [illegible] | 117 | 32 | 136 | 111,000 | 42,492 | [illegible] |
| 30 | | | | | | | | | | | | | | 60 | | | |
| 31 | | | | | | | | | | | | | | | | | |

Note (1) Iodine demand as sulfide

TABLE A-?  CARBONATION BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

APRIL 19??

| Day | Hours | [illegible] | INFLUENT pH | INFLUENT Alk. | INFLUENT SOLIDS TOTAL Total | INFLUENT SOLIDS TOTAL Vol. | INFLUENT SUSPENDED Total | INFLUENT SUSPENDED Vol. | INFLUENT DISSOLVED Total | INFLUENT DISSOLVED Vol. | [illegible] | [illegible] | [illegible] | EFFLUENT pH | EFFLUENT Alk. | EFFLUENT SOLIDS TOTAL Total | EFFLUENT SOLIDS TOTAL Vol. | EFFLUENT SUSPENDED Total | EFFLUENT SUSPENDED Vol. | EFFLUENT DISSOLVED Total | EFFLUENT DISSOLVED Vol. | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | SLUDGE [illegible] | SLUDGE [illegible] | SLUDGE [illegible] | SLUDGE [illegible] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 960 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 134 | 144 | [illegible] | 420 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 234 | [illegible] | [illegible] | [illegible] |
| 2 | 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 180 | 4,734 | 718 | 796 | 368 | 3,436 | [illegible] | 4 | 780 | 810 | [illegible] | 12 | 388 | [illegible] | [illegible] | [illegible] |
| 3 | 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 140 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 284 | [illegible] | [illegible] | 1,342 |
| 4 | 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 140 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 132 | [illegible] | [illegible] | [illegible] |
| 5 | 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 230 | [illegible] | [illegible] | [illegible] |
| Carbonation basin not in operation; tan tannery waste [illegible] (used as primary settling basin) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | 24 | See Note 2) | 11.6 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | Trace | 600 | 620 | [illegible] | [illegible] | 118 | [illegible] | [illegible] | [illegible] |
| 25 | 24 | [illegible] | 11.6 | 660 | [illegible] | 1,214 | 614 | 191 | 2,462 | 884 | 7 | 590 | 960 | [illegible] | [illegible] | 4,272 | 966 | 450 | 130 | 3,820 | 836 | 1 | 1,520 | 590 | [illegible] | [illegible] | 64 | 64,290 | 24,366 | [illegible] |
| 26 | 24 | [illegible] | [illegible] | 670 | 4,560 | [illegible] | 410 | 194 | [illegible] | 888 | 6 | 640 | [illegible] | [illegible] | 140 | 5,040 | 812 | 460 | 204 | 4,180 | 648 | [illegible] | 780 | 560 | 60 | [illegible] | 96 | 110,760 | 32,676 | [illegible] |
| 27 | 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 28 | 24 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| 29 | 24 | [illegible] | 11.4 | [illegible] | [illegible] | 376 | [illegible] | 122 | [illegible] | 836 | 12 | 630 | 1,270 | [illegible] | [illegible] | 4,970 | 912 | 614 | 230 | 4,356 | 682 | 1 | 460 | 630 | [illegible] | [illegible] | 44 | 49,940 | 16,990 | [illegible] |
| 30 | 24 | [illegible] | [illegible] | 620 | [illegible] | 438 | [illegible] | [illegible] | 3,918 | 432 | 4 | 670 | 1,270 | 12.4 | [illegible] | 4,840 | 536 | 604 | 218 | 4,236 | 318 | 1 | [illegible] | 670 | 66 | [illegible] | 60 | 61,316 | 19,018 | [illegible] |

Notes: 1) Iodine demand as sulfide.
2) Began adding effluent of primary settling basin in place of tan [illegible] and beam house mixed wastes.

[illegible] gpm of water substituted for primary settling basin effluent April 27 and 28 - no tannery waste available.

## TABLE A-9 CARBONATION BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

MAY, 1968

| | | | | INFLUENT | | | | | | | | | | | | | EFFLUENT | | | | | | | | | | | | | SLUDGE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | SOLIDS, mg/l | | | | | | | | | | | | | SOLIDS, mg/l | | | | | | | | | | | | | | | | |
| | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | | | | | | |
| Day of Month | Hours of Operation | Primary Effl Flow, gpm | Temperature °F | pH | Alkalinity to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, mg/l | BOD mg/l | Calcium mg/l CaCO3 | Sulfide mg/l | Chromium mg/l | pH | Alkalinity to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, mg/l | BOD mg/l | Calcium mg/l CaCO3 | Sulfide mg/l | Chromium mg/l | Volume Drawn, gals | Total Solids, mg/l | Total Vol Solids, mg/l | Calcium mg/l CaCO3 | Sulfide mg/l | Chromium mg/l |
| 1 | 24 | | | 11.5 | 590 | 5,286 | 1,094 | 530 | 294 | 4,756 | 800 | 2.0 | 810 | 993 | | | 9.6 | 135 | 5,614 | 1,000 | 464 | 210 | 5,150 | 790 | Trace | 665 | | 70(1) | | 236 | 106,062 | 37,702 | | | |
| 2 | 24 | | | 11.7 | 660 | 5,632 | 1,262 | 526 | 376 | 5,106 | 886 | 0.5 | 1,080 | 993 | | | 10.8 | 205 | 4,812 | 922 | 510 | 222 | 4,302 | 700 | 1.0 | 770 | 566 | | | 60 | 118,790 | 43,558 | | | |
| 3 | 24 | | 67 | | | 5,394 | 1,020 | 556 | 184 | 4,838 | 836 | 1.5 | 848 | 1,070 | | | | | 4,922 | 1,020 | 614 | 294 | 4,308 | 726 | Trace | 848 | 764 | | | 88 | 38,392 | 10,972 | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 24 | | 64 | No meter | | 4,828 | 1,254 | 476 | 394 | 4,352 | 860 | 1.0 | 950 | 974 | 78 | 4.3 | No meter | | 4,136 | 944 | 324 | 52 | 3,812 | 892 | 0.3 | 770 | 606 | 69 | 3.2 | 28 | 54,864 | 8,564 | 16,200 | 160 | 226 |
| 7 | 24 | | 72 | 11.8 | 565 | 5,740 | 1,076 | 610 | 278 | 5,130 | 798 | 1.0 | 1,030 | 881 | | | 9.7 | 100 | 10,812 | 2,156 | 700 | 436 | 10,112 | 1,720 | 0.5 | 850 | 533 | | | 68 | 113,398 | 23,236 | | | |
| 8 | 24 | | 70 | No pH meter | | 6,032 | 1,012 | 684 | 340 | 5,348 | 672 | | 1,050 | 1,040 | 88 | 26.6 | | | 5,880 | 958 | 446 | - | 5,434 | 1,048 | | 820 | 727 | 57 | 22.2 | 60 | 48,412 | 15,688 | 14,200 | - | 279 |
| 9 | 24 | | 68 | No pH meter | | 3,176 | 506 | 292 | 130 | 2,884 | 376 | | 470 | 360 | | | | | 4,300 | 544 | 492 | 224 | 3,808 | 320 | | 560 | 505 | 19(1) | | 48 | 88,256 | 25,724 | | | |
| 10 | 24 | | 65 | 11.9 | 555 | 5,790 | 1,244 | 646 | 244 | 5,144 | 1,000 | 0.8 | 500 | 937 | | | 10.1 | 380 | 5,326 | 1,128 | 488 | 308 | 4,838 | 820 | 0.7 | 580 | 719 | 113(1) | | 64 | 102,404 | 29,592 | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 25 | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | 24 | | 66 | 11.6 | 525 | 5,372 | 1,200 | 674 | 374 | 4,698 | 826 | 4.0 | 640 | 816 | | | 10.1 | 145 | 3,926 | 776 | 410 | 150 | 3,516 | 626 | 0.3 | 420 | 525 | | | 32 | 67,960 | 27,556 | | | |
| 14 | 24 | | 60 | 11.8 | 625 | 4,804 | 964 | 450 | 100 | 4,354 | 864 | 0.7 | 655 | 929 | 82 | 1.8 | 10.5 | 155 | 4,398 | 862 | 432 | 164 | 3,966 | 698 | 0.5 | 630 | 622 | 70 | 1.7 | 72 | 110,590 | 36,794 | 48,600 | 120 | 135 |
| 15 | 24 | | 66 | 12.0 | 545 | | | | | | | 3.3 | | | | | 11.5 | 285 | | | | | | | 1.2 | | | | | 60 | | | | | |
| 16 | 24 | | | 12.0 | 685 | 8,848 | 1,164 | 618 | 232 | 8,230 | 932 | 3.0 | 915 | 1,010 | 79 | 12.5 | 11.1 | 230 | 5,964 | 886 | 536 | 216 | 5,428 | 670 | 1.8 | 810 | 727 | 69 | 12.5 | 52 | 109,210 | 39,752 | 48,000 | 162 | 771 |
| 17 | 24 | | | 12.1 | 1,020 | 5,366 | 1,444 | 462 | 354 | 4,904 | 1,190 | 2.0 | 1,110 | 1,450 | | | 11.2 | 235 | 4,726 | 1,062 | 670 | 298 | 4,056 | 764 | 0.5 | 680 | 848 | | | 36 | 132,414 | 46,384 | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 9 | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | 24 | | 65 | 11.8 | 680 | 6,252 | 1,412 | 818 | 426 | 5,434 | 986 | 2.0 | 1,000 | 1,180 | | | 11.3 | 330 | 5,614 | 1,010 | 618 | 146 | 4,996 | 864 | 0.7 | 920 | 1,000 | | | 44 | 82,316 | 34,796 | | | |
| 21 | 24 | | 62 | 11.6 | 780 | 11,104 | 2,322 | 1,860 | 1,242 | 9,244 | 1,080 | 3.8 | 1,405 | 1,100 | 73 | 22.6 | 11.0 | 335 | 9,820 | 3,152 | 1,122 | 1,842 | 8,698 | 1,310 | 2.0 | 1,070 | 608 | 66 | 22.6 | 28 | 89,420 | 32,580 | 30,400 | 88 | 146 |
| 22 | 24 | | 62 | 11.7 | 705 | 5,862 | 1,594 | 676 | 326 | 5,186 | 1,268 | 5.0 | 1,100 | 1,160 | | | 11.4 | 385 | 6,144 | 1,398 | 838 | 274 | 5,306 | 1,124 | 2.0 | 980 | 1,060 | | | 52 | | | | | |
| 23 | 24 | | 61 | 11.8 | 760 | 7,772 | 1,272 | 800 | 443 | 6,972 | 834 | 4.0 | 1,000 | 1,140 | 70 | 12.6 | 11.5 | 480 | 6,410 | 1,014 | 618 | 268 | 5,792 | 746 | 1.3 | 720 | | 112 | 7.8 | 42 | 62,242 | 22,862 | 27,200 | 155 | 402 |
| 24 | 24 | | | 11.5 | 560 | 4,000 | 946 | 488 | 194 | 3,512 | 752 | 1.2 | 1,100 | 800 | | | 10.9 | 270 | 4,388 | 912 | 430 | 118 | 3,958 | 794 | 0.8 | 840 | 676 | | | 34 | 85,628 | 28,196 | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 16 | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | 24 | | 74 | 11.8 | 625 | 5,012 | 1,112 | 384 | 234 | 4,628 | 878 | 2.5 | 890 | 917 | 134 | 12.6 | 9.3 | 65 | 4,392 | 964 | 644 | 212 | 3,748 | 752 | 1.5 | 860 | 606 | 98 | 6.1 | 40 | 103,996 | 37,862 | - | 396 | 385 |
| 28 | 24 | | 65 | 11.7 | 760 | 6,854 | 1,394 | 798 | 306 | 6,056 | 1,088 | 8.0 | 855 | 979 | | | 9.1 | 110 | 6,196 | 994 | 510 | 138 | 5,686 | 856 | 0.8 | 710 | 660 | | | 44 | 89,536 | 38,988 | | | |
| 29 | 24 | | 60 | 11.4 | 625 | 4,752 | 1,058 | 616 | 358 | 4,136 | 700 | 6.0 | 710 | 769 | 85 | 13.2 | 9.2 | 135 | 4,946 | 906 | 548 | 148 | 4,398 | 758 | 2.0 | 550 | 598 | 41 | 5.0 | 56 | 79,942 | 25,458 | 42,100 | 113 | 910 |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | 24 | | | 11.6 | 715 | 4,508 | 1,118 | 582 | 336 | 3,926 | 782 | 3.5 | 765 | 1,030 | | | 10.4 | 125 | 3,078 | 604 | 366 | 118 | 2,712 | 486 | Trace | 345 | 505 | | | 43 | 97,678 | 33,566 | | | |

2 gpm of water substituted for primary settling basin effluent April 4, 5, 11, 12, 18, 19, 25, 26, and 30. Tannery waste unavailable on these days

Note (1) Iodine demand as sulfide

## TABLE A-10. CARBONATION BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

### JUNE, 1968

| Day of Month | Hours of Operation | Primary Effl. Flow, gals | INFLUENT pH | INFLUENT Alkalinity to pH 8.3 | INFLUENT Settleable Solids, ml/l | INFLUENT BOD mg/l | INFLUENT Sulfide mg/l | EFFLUENT pH | EFFLUENT Alkalinity to pH 8.3 | EFFLUENT Settleable Solids, ml/l | EFFLUENT BOD mg/l | EFFLUENT Sulfide mg/l | SLUDGE Volume Drawn, gals | SLUDGE Sulfide mg/l |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | | | | | | 10 | |
| 2 | | | | | | | | | | | | | | |
| 3 | 24 | 5 | 11.1 | 330 | 1.5 | 615 | | 8.7 | 55 | Trace | 570 | | 26 | |
| 4 | 24 | 5 | 11.4 | 450 | 1.4 | 795 | | 8.9 | 80 | 0.1 | 705 | | 48 | |
| 5 | 24 | 5 | 11.6 | 610 | 2.0 | 1,100 | | 9.5 | 110 | 0.1 | 910 | | 44 | |
| 6 | 24 | 5 | 10.9 | 415 | 1.0 | 975 | | 10.2 | 290 | 1.0 | 735 | | 48 | |
| 7 | 24 | 5 | 11.4 | 675 | 3.0 | 1,410 | | 11.3 | 530 | 0.2 | 1,125 | | 29 | |
| 8 | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | |
| 10 | 24 | 5 | 11.1 | 325 | 5.0 | 1,030 | | 8.7 | 50 | 1.3 | 710 | | 40 | |
| 11 | 24 | 5 | 10.9 | 285 | 4.0 | 1,050 | | 8.8 | 55 | Trace | 900 | | 52 | |
| 12 | 24 | 5 | 12.0 | 830 | 1.0 | 970 | | 9.6 | 105 | 0.3 | 870 | | 30 | |
| 13 | 24 | 5 | 12.0 | 580 | 0.5 | 780 | | 9.2 | 80 | 0.2 | 450 | | 23 | |
| 14 | 24 | 5 | 11.8 | 770 | 0.2 | 720 | | 9.2 | 60 | 1.5 | 440 | | 42 | |
| 15 | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | |
| 17 | 24 | 5 | 11.6 | 630 | 0.9 | | 100 | 9.6 | 100 | 0.8 | 510 | 52 | 26 | 94 |
| 18 | 24 | 5 | 11.5 | 620 | 0.3 | | 61 | 9.0 | 95 | Trace | 870 | 45 | 44 | 159 |
| 19 | 24 | 5 | 11.7 | 780 | 1.5 | | 46 | 9.5 | 110 | 1.3 | 1,000 | 33 | 48 | 147 |
| 20 | 24 | 5 | 11.4 | 380 | 0.6 | | 52 | 9.0 | 80 | 0.8 | 645 | 55 | 34 | 170 |
| 21 | 24 | 5 | 11.3 | 490 | 0.7 | | 39 | 8.9 | 60 | 0.3 | 780 | 28 | 34 | 122 |
| 22 | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | |
| 24 | 24 | 5 | 11.1 | 375 | 1.2 | | | 8.8 | 70 | 0.4 | 1,120 | | 30 | |
| 25 | 24 | 5 | 11.0 | 300 | 2.5 | | | 8.5 | 40 | 0.1 | 835 | | 40 | |
| 26 | 24 | 5 | 11.2 | 435 | 0.8 | | | 8.8 | 65 | 0.2 | 1,300 | | 29 | |
| 27 | 24 | 5 | 11.3 | 315 | 0.5 | | | 8.8 | 70 | 0.4 | 510(1) | | 8 | |
| 28 | 24 | 5 | 11.5 | 750 | 1.3 | | | 9.1 | 70 | 0.5 | 785 | | 66 | |
| 29 | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | |

(1) 3-day BOD

## TABLE A-11. CARBONATION BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

JULY, 1968

| Day of Month | Hours of Operation | Primary Effl. Flow, gals | INFLUENT pH | INFLUENT Alkalinity to pH 8.3 | INFLUENT Settleable Solids, ml/l | EFFLUENT pH | EFFLUENT Alkalinity to pH 8.3 | EFFLUENT Settleable Solids, ml/l | EFFLUENT BOD mg/l | SLUDGE Volume Drawn, gals |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24 | 5 | 11.4 | 470 | 0.6 | 9.3 | 85 | 0.3 | 960 | 34 |
| 2 | 24 | 5 | 11.3 | 450 | 0.7 | 8.6 | 80 | 1.5 | 960 | 44 |
| 3 | 24 | 5 | 11.5 | 595 | 2.5 | 9.1 | 75 | 0.2 | 1,000 | 48 |
| 4 | | | | | | | | | | |
| 5 | 24 | 5 | 11.5 | 660 | 0.5 | 10.5 | 20 | 0.4 | | 44 |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | 24 | 5 | | | | | | | 992 | 20 |
| 9 | 24 | 5 | 11.4 | 675 | 2.5 | 11.0 | 435 | 0.2 | 1,380 | 52 |
| 10 | 24 | 5 | 11.4 | 605 | 0.3 | 10.2 | 160 | Trace | 755 | 52 |
| 11 | 24 | 5 | | 665 | 0.7 | 9.5 | 110 | 0.5 | 855 | 44 |
| 12 | 12 | 5 | | | | | | | | 16 |

Note: 2 gpm of water substituted for primary basin effluent July 4, 6, and 7. Tannery waste unavailable.

### TABLE A-12. ACTIVATED SLUDGE BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

### JANUARY, 1968

| | | FLOWS, gpm | | | | INFLUENT SANITARY SEWAGE | | | | | | | | MIXED LIQUOR | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | SOLIDS, mg/l | | | | | | | | | | | | |
| | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | | |
| Day of Month | Hours Operated | Sanitary Sewage | Carbonation Basin Effl. | Return Sludge | Total | Total | Vol. | Total | Vol. | Total | Vol. | Settleable Solids, ml/l | BOD mg/l | Temperature °F | pH | Total Solids mg/l | Total Vol. Solids, mg/l | Settleable Solids, mg/l |
| 8 | | | | | | 676 | 284 | 240 | 151 | 436 | 133 | 18 | 279 | | | | | |
| 8 | 12.5 | 2 | 0 | 1 | 3 | | | | | | | | | 80 | | | | |
| 9 | 20 | 2 | 0 | 1 | 3 | 744 | 442 | 360 | 272 | 384 | 170 | 10.5 | 279 | | 6.45 | 600 | 476 | 10 |
| 10 | 24 | 2 | 0 | 1 | 3 | 614 | 332 | 270 | 0 | 344 | 332 | 8.0 | 276 | 70 | 7.2 | 600 | 518 | 11 |
| 11 | 24 | 2 | 0 | 1 | 3 | | | | | | | | | 71 | | | 790 | |
| 12 | 24 | 2 | 0 | 1 | 3 | | | | | | | 10 | | | | 1,020 | | |
| 13 | 24 | 2 | 0 | 0.5 | 2.5 | | | | | | | | | | | | | |
| 14 | 24 | 2 | 0 | 0.5 | 2.5 | 848 | 676 | 458 | 418 | 390 | 258 | 20 | 290 | 74 | | | | 80 |
| 15 | 8 | 2 | 0 | 0.5 | 2.5 | 744 | 404 | 330 | 174 | 614 | 230 | | 250 | 76 | | 1,680 | 1,372 | |
| 15 | 16 | 2 | 0 | 1 | 3 | | | | | | | | | 78 | | | | |
| 16 | 24 | 2 | 0 | 1 | 3 | 786 | 476 | 276 | 230 | 510 | 246 | 3.5 | | | | 1,540 | 908 | 80 |
| 17 | 24 | 2 | 0 | 1 | 3 | 640 | 314 | 150 | 118 | 490 | 196 | 4.5 | 201 | 67 | | 1,696 | 1,208 | 120 |
| 18 | 24 | 2 | 0 | 1 | 3 | 576 | 280 | 62 | 84 | 514 | 196 | 3.5 | 221 | 68 | | 2,188 | 1,672 | 115 |
| 19 | 24 | 2 | 0 | 1 | 3 | | | | | | | 6.5 | | | | 1,392 | 1,016 | |
| 20 | 24 | 2 | 0 | 1 | 3 | 496 | 424 | 38 | 244 | 458 | 180 | 4.5 | | | | | | |
| 21 | 24 | 2 | 0 | 1 | 3 | 618 | 288 | | | 532 | 228 | 2.5 | 185 | | | | | |
| 22 | 24 | 2 | 0 | 1 | 3 | 572 | 202 | | 30 | 600 | 172 | 0.5 | 201 | 78 | | 1,508 | 1,092 | 80 |
| 23 | 17 | 2 | 0 | 1 | 3 | 690 | 292 | 90 | 44 | 600 | 248 | 0.75 | | | | 1,364 | 850 | 56 |
| 23 | 7 | 2 | 0.5 | 1 | 3.5 | | | | | | | | | | | | | |
| 24 | 17 | 2 | 0 | 1 | 3 | | | | | | | 1.0 | | 74 | | | | 50 |
| 24 | 7 | 2 | 0.5 | 1 | 3.5 | | | | | | | | | 74 | | | | |
| 25 | 12 | 2 | 0 | 1 | 3 | | | | | | | | | | | | | |
| 25 | 12 | 2 | 0.5 | 1 | 3.5 | | | | | | | | | | | | | |
| 26 | 22 | 2 | 0 | 1 | 3 | | | | | | | T | | 69 | | | | |
| 26 | 2 | 2 | 0.5 | 1 | 3.5 | | | | | | | | | 69 | | | | |
| 27 | 18 | 2 | 0 | 1 | 3 | | | | | | | 3 | | | | | | |
| 27 | 6 | 1 | 0 | 1 | 2 | | | | | | | | | | | | | |
| 28 | 24 | 1 | 0 | 1 | 2 | 810 | 370 | 118 | 112 | 692 | 258 | 1.25 | 288 | 78 | | | | |
| 29 | 7 | 1 | 1 | 1 | 2 | 742 | 312 | 76 | 80 | 666 | 232 | 2.5 | 385 | 83 | | 1,280 | 276 | 35 |
| 29 | 11 | 1 | 0 | 1 | 2 | | | | | | | | | 83 | | | | |
| 29 | 6 | 2 | 0 | 1 | 3 | | | | | | | | | 83 | | | | |
| 30 | 13 | 2 | 1 | 1 | 4 | 1,124 | 564 | 358 | 282 | 766 | 282 | 8.0 | 450 | 78 | | 2,124 | 1,092 | 60 |
| 30 | 11 | 2 | 0 | 1 | 3 | | | | | | | | | 78 | | | | |
| 31 | 1 | 2 | 0 | 1 | 3 | | | | | | | T | 344 | 72 | | 2,846 | 1,594 | 120 |
| 31 | 23 | 2 | 1 | 1 | 4 | | | | | | | | | 72 | | | | |

TABLE A-13 ACTIVATED SLUDGE BASIN OPERATION AND ANALYSES
OF COMPOSITE SAMPLES
FEBRUARY, 1968

| | FLOWS, gpm | | | | | INFLUENT SANITARY SEWAGE | | | | | | | | MIXED LIQUOR | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | SOLIDS, mg/l | | | | | | | | | | | |
| | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | |
| Day of Month | Hours of Operation | Sanitary Sewage | Carbonation Basin Effl | Return Sludge | Total | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, ml/l | BOD mg/l | Temperature °F | Total Solids, mg/l | Total Vol. Solids, mg/l | Settleable Solids, ml/l |
| 1 | 15 | 2 | 1 | 1 | 4 | 987 | 322 | 82 | 122 | 905 | 200 | T | 235 | 72 | 3,348 | 1,818 | 120 |
| 1 | 9 | 2 | 0 | 1 | 3 | | | | | | | | | | | | |
| 2 | 24 | 2 | 0 | 1 | 3 | | | | | | | T | | 74 | 4,042 | 1,844 | 120 |
| 3 | 18 | 2 | 0 | 1 | 3 | | | | | | | 3.5 | | | | | |
| 3 | 6 | 1 | 0 | 1 | 2 | | | | | | | | | | | | |
| 4 | 24 | 1 | 0 | 1 | 2 | | | | | | | T | | | | | 0 |
| 5 | 4 | 1 | 0 | 1 | 2 | 2,360 | 896 | 188 | 60 | 2,172 | 836 | T | 136 | | | | 100 |
| 5 | 20 | 1 | 1 | 1 | 3 | | | | | | | | | 77 | | | |
| 6 | 7 | 2 | 0 | 1 | 3 | | | | | | | | 140 | | 5,572 | 2,668 | |
| 6 | 17 | 2 | 1 | 1 | 4 | | | | | | | | | 78 | | | |
| 7 | 2 | 0 | 0 | 1 | 1 | | | | | | | T | | | | | |
| 7 | 6 | 2 | 0 | 1 | 3 | | | | | | | | | | | | |
| 7 | 16 | 2 | 1 | 1 | 4 | | | | | | | | | 74 | | | |
| 8 | 11 | 2 | 0 | 1 | 3 | | | | | | | | | | | | |
| 8 | 13 | 2 | 1 | 1 | 4 | | | | | | | | | | | | |
| 9 | 19 | 2 | 1 | 1 | 4 | | | | | | | | | 71 | | | |
| 9 | 5 | 2 | 0 | 1 | 3 | | | | | | | | | | | | |
| 10 | 5 1/2 | 2 | 1 | 1 | 4 | | | | | | | | | | | | |
| 10 | 12 1/2 | 2 | 0 | 1 | 3 | | | | | | | 12 | | | | | |
| 10 | 6 | 1 | 0 | 1 | 2 | | | | | | | | | | | | |
| 11 | 24 | 1 | 0 | 1 | 2 | | | | | | | T | | | | | 0 |
| 12 | 8 | 2 | 0 | 1 | 3 | | | | | | | 24 | | 69 | | | |
| 12 | 16 | 2 | 1 | 1 | 4 | | | | | | | | | | | | |
| 13 | 24 | 2 | 1 | 1 | 4 | | | | | | | 30 | | 69 | | | |
| 14 | 24 | 2 | 1 | 1 | 4 | | | | | | | 20 | | | | | |
| 15 | 24 | 2 | 1 | 1 | 4 | | | | | | | 17 | | 72 | | | |
| 16 | 8 | 2 | 1 | 1 | 4 | | | | | | | 12 | 473 | | | | |
| 16 | 16 | 2 | 2 | 1 | 5 | | | | | | | | | 70 | | | |
| 17 | 16 | 2 | 0 | 1 | 3 | | | | | | | 11 | | | | | |
| 17 | 8 | 1 | 0 | 1 | 2 | | | | | | | | | | | | |
| 18 | 20 | 1 | 0 | 1 | 2 | 812 | 312 | 180 | 164 | 632 | 148 | 7.5 | 182 | | 4,320 | 1,332 | |
| 18 | 4 | 1 | 2 | 1 | 4 | | | | | | | | | | | | |
| 19 | 24 | 2 | 2 | 1 | 5 | 656 | 260 | | | | | 6.0 | 157 | 75 | | | 6.5 |
| 20 | 8 | 2 | 1 | 1 | 4 | | | | | | | 3.0 | | | 4,252 | 384 | |
| 20 | 16 | 2 | 2 | 1 | 5 | | | | | | | | | 68 | | | |
| 21 | 24 | 2 | 1 | 1 | 4 | | | | | | | | 420 | 65 | | | |
| 22 | 24 | 1 1/2 | 1 | 1 | 3 1/2 | | | | | | | T | | 68 | 3,300 | 1,188 | |
| 23 | 15 1/2 | 2 | 1 | 1 | 4 | | | | | | | | | | | | |
| 23 | 8 1/2 | 2 | 0 | 1 | 3 | | | | | | | | | | | | |
| 24 | 24 | 1 | 0 | 1 | 2 | | | | | | | 10 | | 84 | | | |
| 25 | 24 | 1 | 0 | 1 | 2 | | | | | | | 2 | | 72 | | | |
| 26 | 15 | 2 | 2 | 1 | 5 | | | | | | | 4 | | 76 | | | |
| 26 | 9 | 1 | 0 | 1 | 2 | | | | | | | | | | | | |
| 27 | 24 | 2 | 2 | 1 | 5 | 1,988 | 260 | 148 | 136 | 1,840 | 124 | | | 64 | | | |
| 28 | 24 | 2 | 2 | 1 | 5 | 1,260 | 388 | 312 | 224 | 948 | 164 | | | 67 | 5,228 | 1,500 | 13 |
| 29 | 14 | 2 | 2 | 1 | 5 | 712 | 412 | 344 | 292 | 368 | 120 | | | | 3,036 | 828 | |
| 29 | 10 | 2 | 0 | 1 | 3 | | | | | | | | | | | | |

TABLE A-14 ACTIVATED SLUDGE BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

MARCH, 1968

| FLOWS, gpm | | | | | | INFLUENT SANITARY SEWAGE | | | | | | | | | | | | | MIXED LIQUOR | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | SOLIDS, mg/l | | | | | | | | | | SOLIDS, mg/l | | | | | | | |
| | | | | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | |
| Day of Month | Hours Operated | Sanitary Sewage | Carbonation Basin Eff | Return Sludge | Total | Temperature °F | pH | Acidity to pH 8.3 | Total | Vol | Total | Vol | Total | Vol | Settleable Solids, ml/l | BOD mg/l | Temperature °F | pH | Total | Vol. | Total | Vol. | Total | Vol. | Settleable Solids, ml/l | Sludge Vol Index |
| 1 | 15 | 2 | 2 | 1 | 5 | | | | | | | | | | | | | | 3,740 | 732 | | | | | | |
| 1 | 9 | 2 | 1 | 1 | 4 | | | | | | | | | | | | | | | | | | | | | |
| 2 | 18 | 2 | - | 1 | 3 | | | | | | | | | | | | | | | | | | | | | |
| 2 | 6 | 1 | - | 1 | 2 | | | | | | | | | | 12 | | 64 | | | | | | | | | |
| 3 | 24 | 1 | - | 1 | 2 | | | | 1,460 | 880 | 826 | 708 | 644 | 172 | 16 | 221 | 66 | | | | | | | | | |
| 4 | 12 | 1 | - | 1 | 2 | | | | 828 | 452 | 328 | 296 | 300 | 156 | | 198 | 70 | | 2,600 | 1,124 | 1,328 | 924 | 1,272 | 200 | | |
| 4 | 12 | 2 | 2 | 1 | 5 | | | | | | | | | | | | | | | | | | | | | |
| 5 | 24 | 2 | 2 | 1 | 5 | | 6.9 | 35 | | | | | | | 7.5 | | | | 3,020 | 1,320 | 1,572 | 1,312 | 1,448 | 136 | | |
| 6 | 24 | 2 | 2 | 1 | 5 | 64 | | | | | | | | | 13 | | 65 | | | | | | | | | |
| 7 | 24 | 2 | 2 | 1 | 5 | 59 | 7.2 | 30 | | | | | | | 13 | | 64 | | | | | | | | | |
| 8 | 24 | 2 | 2 | 1 | 5 | 57 | 7.1 | 60 | 756 | 448 | 292 | 228 | 464 | 220 | 13 | | 61 | | | | | | | | | |
| 9 | 18 | 2 | - | 1 | 3 | | | | | | | | | | | | | | | | | | | | | |
| 9 | 6 | 1 | - | 1 | 2 | | | | | | | | | | | | | | | | | | | | | |
| 10 | 19 | 1 | - | 1 | 2 | 63 | | | | | | | | | | | 70 | | | | | | | | | |
| 10 | 5 | 1 | 2 | 1 | 4 | 66 | | | 716 | 428 | 264 | 228 | 452 | 200 | 14 | | 72 | | | | | | | | | |
| 11 | 10 | 1 | 2 | 1 | 4 | 70 | | | | | | | | | | | 72 | | | | | | | | | |
| 11 | 14 | 2 | 2 | 1 | 5 | 64 | 7.6 | 20 | 836 | 340 | 284 | 116 | 552 | 224 | 12 | 342 | 69 | | 2,504 | 1,396 | 1,350 | 1,352 | 872 | 44 | | |
| 12 | 24 | 2 | 2 | 1 | 5 | 58 | 7.4 | 20 | 2,672 | 688 | 512 | 292 | 2,160 | 396 | 14 | 292 | 62 | | 4,328 | 1,156 | 1,588 | 928 | 2,740 | 228 | | 157.0 |
| 13 | 24 | 2 | 2 | 1 | 5 | 56 | 7.7 | 20 | 1,604 | 648 | 1,328 | 372 | 1,176 | 276 | 14 | 345 | 63 | | 3,072 | 740 | 580 | 220 | 2,492 | 520 | | 150.0 |
| 14 | 24 | 2 | 2 | 2 | 6 | 55 | 7.5 | 60 | 1,276 | 464 | 420 | 312 | 876 | 152 | 10 | 270 | 59 | | 2,460 | 824 | 824 | 648 | 1,636 | 176 | | 37.4 |
| 15 | 24 | 2 | 2 | 2 | 6 | 54 | 7.6 | 30 | | | | | | | 12 | | 60 | | 4,580 | 740 | 2,380 | 68 | 2,200 | 672 | | |
| 16 | 18 | 2 | - | 2 | 4 | 57 | | | | | | | | | | | 62 | | | | | | | | | |
| 16 | 6 | 1 | - | 2 | 3 | 58 | 7.4 | | | | | | | | 10 | | 61 | | | | | | | | | |
| 17 | 19 | 1 | - | 2 | 3 | 62 | | | | | | | | | | | 62 | | | | | | | | | |
| 17 | 3 | 1 | 2 | 2 | 5 | 63 | | | | | | | | | 13.5 | | | | | | | | | | | |
| 17 | 2 | 0.5 | 2 | 2 | 4.5 | | | | | | | | | | | | | | | | | | | | | |
| 18 | 8 | 1 | 1 | 2 | 4 | 74 | | | | | | | | | | | 71 | | | | 1,550 | | | | | 61.3 |
| 18 | 8 | 1 | - | 2 | 3 | | 7.8 | | | | | | | | 10 | | | | | | | | | | | |
| 18 | 8 | 1 | 2 | 2 | 5 | | | | | | | | | | | | | | | | | | | | | |
| 19 | 24 | 1 | 2 | 2 | 5 | 63 | 7.6 | 30 | | | | | | | 14 | 135 | 68 | | | | 1,850 | | | | | 54.0 |
| 20 | 24 | 1 | 2 | 2 | 5 | 64 | 7.7 | 50 | | | | | | | 9 | 100 | 71 | | | | | | | | | |
| 21 | 24 | 1 | 2 | 2 | 5 | 58 | 8.2 | - | | | | | | | 11 | 200 | 64 | 7.9 | | | | | | | | |
| 22 | 18 | 1 | 2 | 2 | 5 | 64 | 7.9 | 25 | 548 | 256 | 208 | 172 | 340 | 84 | 6 | 103 | 66 | 7.0 | | | | | | | 106 | |
| 22 | 6 | 1 | - | 2 | 3 | | | | | | | | | | | | | | | | | | | | 114 | |
| 23 | 24 | 1 | - | 2 | 3 | 62 | 7.0 | 30 | | | | | | | 1.5 | | 67 | 7.5 | | | | | | | 94 | |
| 24 | 24 | 1 | - | 2 | 3 | 69 | | | | | | | | | 3.0 | | 69 | 7.2 | | | | | | | 81 | |
| 25 | 24 | 1 | 2 | 2 | 5 | 71 | 7.8 | 25 | 520 | 404 | 126 | 140 | 392 | 264 | 6.0 | 115 | 70 | 7.1 | 4,400 | 2,552 | 2,676 | 2,268 | 1,724 | 284 | 90 | |
| 26 | 24 | 1 | 2 | 2 | 5 | 62 | 8.2 | - | 490 | 176 | 184 | 134 | 306 | 30 | 5.5 | 96 | 64 | 7.2 | | | 1,700 | 1,280 | | | 92 | 52.8 |
| 27 | 24 | 1 | 2 | 2 | 5 | 69 | 7.7 | 30 | 532 | 224 | 210 | 210 | 312 | 14 | 4 | 100 | 67 | 6.8 | | | 1,700 | 1,336 | | | 87 | 57.1 |
| 28 | 24 | 1 | 2 | 2 | 5 | | 7.1 | 5 | 476 | 192 | 90 | 70 | 386 | 122 | 4 | 90 | | 6.7 | | | 1,656 | 1,310 | | | 89 | 86.5 |
| 29 | 24 | 1 | 2 | 2 | 5 | | 7.3 | 25 | 464 | 204 | 112 | 132 | 352 | 72 | 1 | 110 | | 7.2 | 1,744 | 1,328 | 800 | | | | 73 | 94.0 |
| 30 | 24 | 1 | - | 2 | 3 | 59 | 7.1 | 30 | | | | | | | 1.5 | | 64 | 6.9 | | | 700 | | | | 109 | 114.5 |
| 31 | 24 | 1 | - | 2 | 3 | 58 | | | | | | | | | | | 61 | 7.0 | | | 750 | | | | 114 | 116.1 |

TABLE A-15 ACTIVATED SLUDGE BASIN OPERATION AND ANALYSES
OF COMPOSITE SAMPLES

APRIL, 1968

| Day of Month | Hours Operated | FLOWS, gpm | | | | INFLUENT SANITARY SEWAGE | | | | | | | | | | | | | MIXED LIQUOR | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sanitary Sewage | Carbonation Basin Eff | Return Sludge | Total | Temperature °F | pH | Acidity to pH 8.3 | SOLIDS, mg/l | | | | | | Settleable Solids, ml/l | BOD mg/l | Temperature °F | pH | SOLIDS, mg/l | | | | | | Settleable Solids, ml/l | Sludge Vol Index |
| | | | | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | |
| | | | | | | | | | Total | Vol | Total | Vol | Total | Vol | | | | | Total | Vol | Total | Vol | Total | Vol | | |
| 1 | 24 | 1 | 2 | 2 | 5 | 68 | 7.4 | 20 | 908 | 354 | 252 | 236 | 656 | 118 | 15 | 270 | 65 | 7.1 | | | 2,072 | 1,510 | | | 95 | 105.0 |
| 2 | 24 | 1 | 2 | 2 | 5 | 61 | 7.7 | | 2,124 | 480 | 488 | 298 | 1,636 | 182 | 15 | 182 | 66 | 6.7 | | | | | | | 112 | |
| 3 | 24 | 1 | 2 | 2 | 5 | | 7.1 | | | | | | | | 6.0 | | | 7.3 | | | 1,400 | | | | 72 | 50 |
| 4 | 24 | 1 | 2 | 2 | 5 | 60 | 6.9 | | | | | | | | 8.0 | | 70 | 7.1 | | | 1,784 | 1,538 | | | 85 | 35.4 |
| 5 | 24 | 1 | 2 | 2 | 5 | 62 | | | | | | | | | | | 72 | 6.9 | | | 1,300 | | | | 93 | 77 |
| 6 | 24 | 1 | - | 2 | 3 | 62 | 7.0 | | | | | | | | 3.5 | | 67 | 6.7 | | | 1,100 | | | | 98 | 77 |
| 7 | 24 | 1 | - | 2 | 3 | 67 | 6.9 | | | | | | | | 9.5 | | 69 | 7.0 | | | 2,100 | | | | 114 | 55 |
| 8 | 24 | 1 | - | 2 | 3 | 75 | | | | | | | | | | | 74 | | | | | | | | 108 | |
| 9 | 24 | 1 | - | 2 | 3 | | | | | | | | | | | | | | | | | | | | 103 | |
| 10 | 24 | 1 | - | 2 | 3 | | | | | | | | | | | | | | | | | | | | | |
| 11 | 24 | 1 | - | 3 | 4 | | | | | | | | | | | | | | | | | | | | 110 | |
| 12 | 24 | 1 | - | 3 | 4 | | | | | | | | | | | | | | | | | | | | | |
| 13 | 24 | 1 | - | 3 | 4 | | | | | | | | | | | | | | | | 2,000 | | | | 122 | 66 |
| 14 | 24 | 1 | - | 3 | 4 | 56 | | | | | | | | | | | 68 | | | | 1,300 | | | | 123 | 93 |
| 15 | 24 | 1 | - | 3 | 4 | 60 | | | | | | | | | | | 63 | | | | | | | | 125 | |
| 16 | 24 | 1 | - | 3 | 4 | 54 | | | | | | | | | | | 66 | | | | | | | | 120 | |
| 17 | 24 | 1 | - | 0.5 | 1.5 | 54 | | | | | | | | | | | 62 | | | | | | | | 116 | |
| 18 | 24 | 1 | - | 1 | 2 | | | | | | | | | | | | | | | | | | | | 110 | |
| 19 | 24 | 1 | - | 1 | 2 | | | | | | | | | | | | | | | | | | | | 109 | |
| 20 | 24 | 1 | - | 1 | 2 | 56 | | | | | | | | | | | 62 | | | | | | | | 97 | |
| 21 | 24 | 1 | - | 1 | 2 | 59 | | | | | | | | | | | 65 | | | | | | | | 85 | |
| 22 | 24 | 1 | - | 1 | 2 | 58 | | | | | | | | | | | 63 | | | | | | | | 97 | |
| 23 | 24 | 1 | - | 1 | 2 | 56 | | | | | | | | | | | 62 | | | | | | | | 91 | |
| 24 | 24 | 1 | 1 | 1 | 3 | 56 | 7.5 | 25 | | | | | | | 7 | | 67 | 7.2 | | | 1,000 | | | | 75 | 63 |
| 25 | 24 | 1 | 1 | 2 | 4 | 52 | 7.5 | 15 | 734 | 328 | 304 | 218 | 430 | 110 | 2 | 195 | 65 | 7.4 | 2,820 | | 1,750 | | | | 81 | 51 |
| 26 | 24 | 1 | 1 | 2 | 4 | 54 | 7.8 | 15 | 512 | 208 | 132 | 112 | 380 | 96 | 5.5 | 94 | 65 | 7.1 | 3,362 | 1,320 | 1,100 | | | | 95 | 91 |
| 27 | 24 | 1 | - | 2 | 3 | 54 | 7.0 | | | | | | | | 1.5 | | 60 | 6.9 | | | 500 | | | | 93 | 160 |
| 28 | 24 | 1 | - | 2 | 3 | 54 | 6.6 | | | | | | | | 2.5 | | 64 | 6.7 | | | 1,700 | | | | 80 | 47 |
| 29 | 24 | 1 | 1 | 2 | 4 | 58 | 8.0 | 50 | 510 | 204 | 114 | 88 | 396 | 116 | 5.0 | 106 | 65 | 6.7 | | | 1,200 | | | | 89 | 79 |
| 30 | 24 | 1 | 2 | 2 | 5 | 55 | 7.8 | 15 | 492 | 180 | 146 | 100 | 346 | 80 | 5.0 | 90 | 62 | 7.1 | 3,854 | 1,638 | 1,938 | 1,508 | 1,916 | 130 | 97 | 62.5 |

Note: Solution of commercial sodium sulfide added to aeration basin as follows:

| Date | Time | Ppm S based on 2 gpm carbonation basin effluent |
|---|---|---|
| 4 2 | 3:00 PM - 5:00 PM | 400 |
| 4 3 - 4 4 | 3:00 PM - 3:00 PM | 50 |
| 4 4 - 4 5 | 3:00 PM - 3:00 PM | 100 |

TABLE A-16. ACTIVATED SLUDGE BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

MAY, 1968

| Day of Month | Hours of Operation | FLOWS, gpm | | | | INFLUENT SANITARY SEWAGE | | | | | | | | | | | | MIXED LIQUOR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Sanitary Sewage | Carbonation Basin Effl. | Return Sludge | Total | Temperature °F | pH | Acidity to pH 8.3 | SOLIDS, mg/l | | | | | | Settleable Solids, ml/l | BOD mg/l | Temperature °F | pH | SUSPENDED SOLIDS mg/l | | Settleable Solids, ml/l | Sludge Vol. Index |
| | | | | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | | | |
| | | | | | | | | | Total | Vol. | Total | Vol. | Total | Vol. | | | | | Total | Vol. | | |
| 1 | 24 | 1 | 2 | 2 | 5 | 63 | | | 526 | 218 | 163 | 136 | 363 | 82 | | 96 | 63 | 7.2 | 2,750 | | 130 | 51 |
| 2 | 24 | 1 | 2 | 2 | 5 | | 7.3 | 20 | 530 | 210 | 174 | 130 | 356 | 80 | 6.0 | 122 | | 7.3 | 3,182 | 2,624 | 130 | 44 |
| 3 | 24 | 1 | 2 | 2 | 5 | 56 | | | 1,220 | 170 | 144 | 74 | 1,076 | 96 | | 98 | 64 | 7.0 | 2,734 | 2,238 | 140 | |
| 4 | 24 | 1 | 0 | 2 | 3 | 60 | | | | | | | | | | | 62 | 7.2 | | | 150 | |
| 5 | 24 | 1 | 0 | 2 | 3 | | | | | | | | | | | | | 7.0 | | | 145 | |
| 6 | 24 | 1 | 2 | 2 | 5 | 62 | | | 448 | 156 | 132 | 96 | 316 | 60 | | 92 | | 7.3 | 3,292 | 2,796 | 171 | 72 |
| 7 | 24 | 1 | 2 | 2 | 5 | 50 | 7.7 | 5 | 532 | 166 | 136 | 118 | 396 | 48 | 1.0 | 97 | 68 | 7.0 | 4,140 | 3,520 | 175 | 42 |
| 8 | 24 | 1 | 2 | 2 | 5 | 60 | | | 528 | 202 | 154 | 68 | 374 | 102 | | 130 | 66 | 7.4 | 3,968 | 3,448 | 180 | 66 |
| 9 | 24 | 1 | 2 | 2 | 5 | 60 | | | 482 | 192 | 126 | 124 | 356 | 66 | | 141 | 67 | 7.2 | 3,016 | 2,036 | 210 | 58 |
| 10 | 24 | 1 | 2 | 2 | 5 | 62 | 6.8 | 100 | 526 | 242 | 186 | 160 | 340 | 82 | 6.0 | 164 | 70 | | 3,784 | 3,288 | 220 | 69 |
| 11 | 24 | 1 | 0 | 2 | 3 | 58 | | | | | | | | | 6.5 | | 66 | | | | 220 | |
| 12 | 24 | 1 | 0 | 2 | 3 | 60 | | | | | | | | | 6.0 | | 65 | 6.8 | | | 220 | |
| 13 | 24 | 1.5 | 3 | 2 | 6.5 | 56 | 7.5 | 15 | 624 | 286 | 204 | 174 | 420 | 112 | 10.0 | 138 | 65 | 7.4 | 3,332 | 2,956 | 230 | 84 |
| 14 | 24 | 1.5 | 3 | 2 | 6.5 | 65 | 7.5 | 15 | 610 | 250 | 230 | 186 | 380 | 74 | 10.0 | 183 | 70 | 7.1 | 3,416 | 2,860 | 230 | 70 |
| 15 | 24 | 1.5 | 3 | 2 | 6.5 | 61 | - | - | | | | | | | | | 70 | | 3,296 | 2,600 | 250 | |
| 16 | 24 | 1.5 | 3 | 2 | 6.5 | | - | - | 556 | 256 | 174 | 166 | 382 | 90 | | 167 | | | | | 280 | |
| 17 | 24 | 1.5 | 3 | 2 | 6.5 | | 7.5 | 15 | 514 | 204 | 128 | 106 | 386 | 98 | 7.0 | 150 | | 7.2 | 5,008 | 3,916 | 350 | |
| 18 | 24 | 1.5 | 0 | 2 | 3.5 | 50 | 7.1 | 20 | | | | | | | 5.0 | | 59 | 7.2 | | | 190 | |
| 19 | 24 | 1.5 | 0 | 2 | 3.5 | 54 | 7.3 | 20 | | | | | | | 5.0 | | 60 | 7.2 | | | 200 | |
| 20 | 24 | 1.5 | 4 | 2 | 7.5 | 55 | 7.8 | 15 | 670 | 220 | 184 | 130 | 486 | 90 | 7.5 | 134 | 66 | 8.2 | 3,124 | 2,204 | 160 | 75 |
| 21 | 24 | 2 | 4 | 2 | 8 | 52 | 8.6 | 20 | 590 | 218 | 194 | 170 | 396 | 48 | 10.0 | 159 | 62 | 7.2 | 4,588 | 2,660 | 160 | 205 |
| 22 | 24 | 2 | 4 | 2 | 8 | 56 | 7.6 | 20 | 584 | 264 | 184 | 196 | 360 | 68 | 11.0 | 142 | 64 | 7.6 | 4,900 | 2,856 | 150 | 33 |
| 23 | 24 | 2 | 4 | 2 | 8 | 57 | 7.8 | 15 | 552 | 180 | 204 | 136 | 348 | 44 | 11.0 | 129 | 68 | 7.0 | 3,936 | | 170 | 45 |
| 24 | 24 | 2 | 4 | 2 | 8 | | 7.8 | 20 | 574 | 48 | 226 | 184 | 348 | 64 | 10.0 | 190 | | 7.4 | 3,608 | 2,352 | 160 | 40 |
| 25 | 12 | 1 | 0 | 2 | [illegible] | 60 | 7.0 | 55 | | | | | | | 7.5 | | 62 | 6.7 | | | 144 | - |
| 26 | 24 | 1 | 0 | 2 | [illegible] | 59 | 7.6 | 45 | | | | | | | 9.5 | | 66 | 6.9 | | | 158 | - |
| 27 | 24 | 2 | [illegible] | 2 | [illegible] | 64 | 7.8 | 45 | 700 | 398 | 186 | 158 | 314 | 150 | 7.5 | 190 | 68 | 7.3 | 2,840 | 2,108 | 155 | 50 |
| 28 | 24 | 2.5 | 5 | 2 | 9.5 | 58 | 7.9 | 45 | 664 | 312 | 234 | 186 | 430 | 126 | 11.0 | 170 | 65 | 6.6 | 3,440 | 2,784 | 200 | 50 |
| 29 | 24 | 2.5 | [illegible] | 2 | 9.5 | 64 | 7.8 | 60 | 786 | 210 | 114 | 106 | 672 | 104 | 4.5 | 125 | 69 | 6.8 | 3,400 | | 170 | 46 |
| 30 | 24 | 0.5 | [illegible] | 2 | 2.5 | 59 | 7.2 | 10 | | | | | | | 5.5 | | 66 | 7.1 | | | 138 | - |
| 31 | 24 | 2.5 | [illegible] | 2 | 9.5 | [illegible] | | | 654 | 266 | 274 | 202 | 380 | 64 | 12.5 | 92 | 66 | | 2,260 | 1,772 | 130 | 55 |

## TABLE A-17. ACTIVATED SLUDGE BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

JUNE, 1968

| | | FLOWS, gpm | | | | INFLUENT SANITARY SEWAGE | | | | | MIXED LIQUOR | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | SOLIDS, mg/l | | | | | | | |
| | | | | | | | | | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | |
| Day of Month | Hours of Operation | Sanitary Sewage | Carbonation Basin Effl. | Return Sludge | Total | Temperature °F | pH | Acidity to pH 8.3 | Settleable Solids, ml/l | BOD mg/l | Temperature °F | pH | Total | Vol. | Total | Vol. | Total | Vol. | Settleable Solids, ml/l | Sludge Vol. Index |
| 1 | 24 | 0.5 | 0 | 2 | 2.5 | 65 | | | | | 68 | | | | | | | | | |
| 2 | 24 | 0.5 | 0 | 2 | 2.5 | 63 | | | | | 68 | | | | | | | | | 63 |
| 3 | 24 | 0.5 | 2 | 2 | 4.5 | 64 | 7.6 | 35 | 3.5 | 51 | 69 | 7.2 | | | 2,084 | 1,740 | | | 140 | 70 |
| 4 | 24 | 0.5 | 2 | 2 | 4.5 | 63 | 7.8 | 5 | 2.5 | 80 | 70 | 7.1 | | | 2,412 | 1,904 | | | 155 | 57 |
| 5 | 24 | 0.5 | 2 | 2 | 4.5 | 62 | 7.9 | 15 | 4.5 | 123 | 68 | 7.1 | | | 2,444 | 1,932 | | | 200 | 81 |
| 6 | 24 | 0.5 | 2 | 2 | 4.5 | 66 | 7.6 | 50 | 5.0 | 140 | 71 | 7.0 | | | | | | | 240 | 91 |
| 7 | 24 | 0.5 | 2 | 2 | 4.5 | 68 | 7.8 | 20 | 5.0 | 130 | 72 | 7.3 | 6,722 | 2,516 | 2,592 | 1,960 | 4,130 | 556 | 300 | 79 |
| 8 | 24 | 0.5 | 0 | 2 | 2.5 | 64 | 7.1 | 30 | 8.0 | | 72 | | | | | | | | | |
| 9 | 24 | 0.5 | 0 | 2 | 2.5 | 68 | 7.5 | - | 7.5 | | 72 | | | | | | | | | |
| 10 | 24 | 0.5 | 2 | 2 | 4.5 | 65 | 7.8 | 20 | 7.0 | 98 | 70 | 7.3 | 5,346 | 2,254 | 3,160 | 2,416 | 2,186 | 38 | 300 | 94 |
| 11 | 24 | 0.5 | 2 | 2 | 4.5 | 60 | 7.7 | 15 | 2.5 | 100 | 68 | 7.0 | | | 4,108 | 3,128 | | | 355 | 127 |
| 12 | 24 | 0.5 | 2 | 2 | 4.5 | 62 | 8.0 | 5 | 3.2 | 156 | 70 | 7.3 | 6,138 | 2,376 | 3,116 | 2,408 | 3,022 | - | 280 | 87 |
| 13 | 24 | 0.5 | 2 | 2 | 4.5 | 60 | 8.3 | 0 | 4.5 | 110 | 70 | 7.4 | 6,780 | 4,440 | 3,164 | 2,440 | 3,616 | 2,000 | 310 | 97 |
| 14 | 24 | 0.5 | 2 | 2 | 4.5 | | 8.2 | 0 | 6.0 | 103 | | 7.2 | | | 3,216 | 2,412 | | | 300 | 109 |
| 15 | 24 | 0.5 | 0 | 2 | 2.5 | 69 | 7.6 | 15 | 3.0 | | 70 | | | | | | | | | |
| 16 | 24 | 0.5 | 0 | 2 | 2.5 | 69 | 7.6 | 20 | 8.0 | | 69 | | | | | | | | | |
| 17 | 24 | 0.5 | 2 | 2 | 4.5 | 62 | 8.1 | 5 | 3.5 | | 68 | 7.3 | 4,296 | 1,684 | 2,404 | 1,744 | 2,892 | - | 250 | 113 |
| 18 | 24 | 0.5 | 2 | 2 | 4.5 | 60 | 8.0 | 10 | 13.0 | | 69 | 6.9 | | | 2,592 | 1,872 | | | 220 | 78 |
| 19 | 24 | 0.5 | 2 | 2 | 4.5 | 64 | 7.9 | 5 | 9.0 | | 71 | 7.0 | | | 2,780 | 2,060 | | | 220 | 88 |
| 20 | 24 | 0.5 | 2 | 2 | 4.5 | 64 | 7.6 | 10 | 8.0 | | 70 | 7.0 | 5,478 | 1,948 | 2,820 | 2,112 | 2,658 | - | 220 | 56 |
| 21 | 24 | 0.5 | 2 | 2 | 4.5 | | 7.2 | 15 | 4.0 | | | 6.9 | | | 2,956 | 2,184 | | | 230 | 74 |
| 22 | 24 | 0.5 | 0 | 2 | 2.5 | 62 | 7.3 | 10 | 0.7 | | 67 | | | | | | | | | 87 |
| 23 | 24 | 0.5 | 0 | 2 | 2.5 | 62 | 7.3 | - | 1.0 | | 66 | | | | | | | | | 136 |
| 24 | 24 | 0.5 | 2 | 2 | 4.5 | | 7.8 | 15 | 7.5 | | | 6.7 | | | 2,260 | 1,704 | | | 200 | 91 |
| 25 | 24 | 0.5 | 2 | 2 | 4.5 | 66 | 7.8 | 45 | 7.0 | | 72 | 6.7 | | | 2,112 | 1,620 | | | 150 | 75 |
| 26 | 24 | 0.5 | 2 | 2 | 4.5 | 64 | 7.5 | 30 | 7.0 | | 72 | 6.7 | | | 2,312 | 1,852 | | | 280 | 104 |
| 27 | 24 | 0.5 | 2 | 2 | 4.5 | 62 | 6.9 | 105 | 7.5 | | 70 | 6.7 | | | 2,612 | 2,124 | | | 280 | 93 |
| 28 | 24 | 0.5 | 2 | 2 | 4.5 | 60 | 7.6 | 25 | 8.0 | | 70 | 7.0 | | | 3,120 | 2,564 | | | 310 | 126 |
| 29 | 24 | 0.5 | 0 | 2 | 2.5 | 56 | 7.0 | 40 | 5.5 | | 68 | | | | | | | | | |
| 30 | 24 | 0.5 | 0 | 2 | 2.5 | 70 | 7.4 | 30 | 2.0 | | 69 | | | | | | | | | 93 |

Note: 10 ppm of phosphate (based on 2 gpm tannery waste flow) added to activated sludge basin 12:00 M 6/18 - 8:00 AM 6/24, and 4:00 PM 6/25 through 6/30.

## TABLE A-18. ACTIVATED SLUDGE BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

JULY, 1968

| | | FLOWS, gpm | | | | SANITARY SEWAGE | | | | | MIXED LIQUOR | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | SUSPENDED SOLIDS, mg l | | | |
| Day of Month | Hours of Operation | Sanitary Sewage | Carbonation Basin Effl. | Return Sludge | Total | Temperature °F | pH | Acidity to pH 8.3 | Settleable Solids, ml/l | BOD mg/l | Temperature °F | pH | Total | Vol. | Settleable Solids, ml/l | Sludge Vol. Index |
| 1 | 24 | 0.5 | 2 | 2 | 4.5 | 76 | 7.5 | 30 | 5.0 | | 78 | 7.0 | 3,212 | 2,584 | 290 | 100 |
| 2 | 24 | 0.5 | 2 | 2 | 4.5 | 75 | 7.9 | 45 | 7.5 | | 79 | 6.9 | 3,280 | 2,628 | 310 | 86 |
| 3 | 24 | 0.5 | 2 | 2 | 4.5 | 74 | 7.1 | 75 | 4.0 | | 76 | 6.7 | 3,268 | 2,624 | 390 | 134 |
| 4 | 24 | 0.5 | 0 | 2 | 2.5 | | 7.0 | 60 | 3.0 | | | 6.9 | | | 290 | - |
| 5 | 24 | 0.5 | 2 | 2 | 4.5 | 68 | 7.9 | 5 | 1.0 | | 70 | 7.0 | | | 300 | - |
| 6 | 24 | 0.5 | 0 | 2 | 2.5 | | | | | | | | | | | |
| 7 | 24 | 0.5 | 0 | 2 | 2.5 | 68 | | | | | 70 | | | | | |
| 8 | 24 | 0.5 | 2 | 2 | 4.5 | 74 | | | | | 74 | | 2,056 | 1,628 | | |
| 9 | 24 | 0.5 | 2 | 2 | 4.5 | | 8.0 | 40 | 7.0 | | | 6.5 | 2,264 | 1,836 | 260 | 104 |
| 10 | 24 | 0.5 | 2 | 2 | 4.5 | 70 | 7.7 | 60 | 9.0 | | 75 | 6.7 | 2,792 | 2,164 | 180 | 62 |
| 11 | 24 | 0.5 | 2 | 2 | 4.5 | 69 | 7.7 | 45 | 5.0 | | 74 | 6.5 | 2,420 | 1,852 | 170 | 61 |
| 12 | 12 | 0.5 | 2 | 2 | 4.5 | | | | | | | 6.2 | 1,896 | | 70 | - |

Notes: 10 ppm of phosphate (based on 2 gpm tannery waste flow) added to activated sludge basin.

Chrome liquor (tannery prepared basic chrome sulfate) added to activated sludge basin in the quantities shown below.

| Date | Ppm Cr based on 2 gpm carbonation basin effluent |
|---|---|
| July 9, 1968 | 40 |
| July 10, 1968 | 80 |
| July 11, 1968 | 120 |
| July 12, 1968 | 160 |

TABLE A-19. SECONDARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

JANUARY, 1968

|  |  |  |  |  | EFFLUENT |  |  |  |  |  |  |  | RETURN SLUDGE |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | FLOW, gpm |  |  | SOLIDS, mg/l |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  | TOTAL |  | SUSPENDED |  | DISSOLVED |  |  |  |  |  |  |
| Day of Month | Hours Operated | Influent | Return Sludge | Effluent | Total | Vol. | Total | Vol. | Total | Vol. | Settleable Solids, ml/l | BOD mg/l | Total Solids, mg/l | Total Vol. Solids, mg/l | Sludge Wasted, gals |
| 8 | 12.5 | 3 | 1 | 2 | 838 | 346 | 392 | 215 | 446 | 131 | 8 | 246 |  |  |  |
| 9 | 20 | 3 | 1 | 2 | 570 | 310 | 164 | 174 | 406 | 136 | Trace | 127 |  |  |  |
| 10 | 24 | 3 | 1 | 2 | 346 | 136 | 140 | 34 | 306 | 102 | Trace | 47.5 |  |  |  |
| 11 | 24 | 3 | 1 | 2 |  |  |  |  |  |  |  |  |  |  |  |
| 12 | 24 | 3 | 1 | 2 |  |  |  |  |  |  | Trace |  |  |  |  |
| 13 | 24 | 3 | 1/2 | 2.5 |  |  |  |  |  |  |  |  |  |  |  |
| 14 | 24 | 3 | 3/8 | 2.6 | 414 | 252 | 68 | - | 346 | 288 |  | 36 |  |  |  |
| 15 | 8 | 3 | 3/8 | 2.6 | (570 | 108 | 64 | - | 506 | 198 |  | 78 |  |  |  |
| 15 | 16 | 3 | 1 | 2 | ( |  |  |  |  |  |  |  |  |  |  |
| 16 | 24 | 3 | 1 | 2 | 576 | 260 | 90 | 116 | 486 | 144 | Trace |  | 2,278 | 1,618 |  |
| 17 | 24 | 3 | 1 | 2 | 624 | 298 | 190 | 164 | 434 | 134 | 1.5 | 78 |  |  |  |
| 18 | 24 | 3 | 1 | 2 | 584 | 310 | 190 | 154 | 394 | 156 | 2 | 104 | 3,740 | 806 | 30 |
| 19 | 24 | 3 | 1 | 2 |  |  |  |  |  |  | 3.5 |  | 2,240 | 1,732 | 45 |
| 20 | 24 | 3 | 1 | 2 | 530 | 240 | 0 | 0 | 554 | 240 | 5.0 |  |  |  | 45 |
| 21 | 24 | 3 | 1 | 2 | 574 | 260 | 52 | 26 | 522 | 234 | 1 | 123 |  |  | 30 |
| 22 | 24 | 3 | 1 | 2 | 740 | 386 | 302 | 262 | 438 | 124 | 75 | 159 |  |  | 15 |
| 23 | 17 | 3 | 1 | 2 | (640 | 248 | 344 | 104 | 396 | 114 | 13 |  |  |  |  |
| 23 | 7 | 3.5 | 1 | 2.5 | ( |  |  |  |  |  |  |  |  |  |  |
| 24 | 17 | 3 | 1 | 2 |  |  |  |  |  |  | (2.5 |  |  |  |  |
| 24 | 7 | 3.5 | 1 | 2.5 |  |  |  |  |  |  | ( |  |  |  |  |
| 25 | 12 | 3 | 1 | 2 |  |  |  |  |  |  |  |  |  |  |  |
| 25 | 12 | 3.5 | 1 | 2.5 |  |  |  |  |  |  |  |  |  |  |  |
| 26 | 22 | 3 | 1 | 2 |  |  |  |  |  |  | (2.5 |  |  |  |  |
| 26 | 2 | 3.5 | 1 | 2.5 |  |  |  |  |  |  | ( |  |  |  |  |
| 27 | 18 | 3 | 1 | 2 |  |  |  |  |  |  | (23 |  |  |  | 30 |
| 27 | 6 | 2 | 1 | 1 |  |  |  |  |  |  | ( |  |  |  |  |
| 28 | 24 | 2 | 1 | 1 | 1,338 | 738 | 682 | 322 | 656 | 416 | 52 | 252 |  |  | 28 |
| 29 | 13 | 3 | 1 | 2 | (1,280 | 276 |  |  |  |  | 8 | 120 | 2,068 | 880 |  |
| 29 | 11 | 2 | 1 | 1 | ( |  |  |  |  |  |  |  |  |  |  |
| 30 | 13 | 4 | 1 | 3 | (1,290 | 270 | 122 | 124 | 1,168 | 146 | 0 | 53 | 4,092 | 2,456 | 15 |
| 30 | 11 | 3 | 1 | 2 | ( |  |  |  |  |  |  |  |  |  |  |
| 31 | 1 | 3 | 1 | 2 |  |  |  |  |  |  | (Trace | 34 |  |  |  |
| 31 | 23 | 4 | 1 | 3 |  |  |  |  |  |  | ( |  |  |  | 45 |

TABLE A-20. SECONDARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

FEBRUARY, 1968

| Day of Month | Hours Operated | FLOWS, gpm |  |  | EFFLUENT |  |  |  |  |  |  |  | RETURN SLUDGE |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Influent | Return Sludge | Effluent | SOLIDS, mg l |  |  |  |  |  | Settleable Solids, ml l | BOD mg l | Total Solids, mg | Total Vol Solids, mg | Sludge Wasted, gal |
|  |  |  |  |  | TOTAL |  | SUSPENDED |  | DISSOLVED |  |  |  |  |  |  |
|  |  |  |  |  | Total | Vol | Total | Vol | Total | Vol |  |  |  |  |  |
| 1 | 1 | 4 | 1 | 3 | (1,497 | 199 | 69 | 24 | 1,428 | 175 | Trace | 24 | 7,080 | 4,550 | 120 |
| 1 | [illegible] | 3 | 1 | 2 | ( |  |  |  |  |  |  |  |  |  |  |
| 2 | 24 | 3 | 1 | 2 |  |  |  |  |  |  | 0 |  | 16,286 | 10,460 | 150 |
| 3 | 18 | 3 | 1 | 2 |  |  |  |  |  |  | 0 |  |  |  | 140 |
| 3 | 6 | 2 | 1 | 1 |  |  |  |  |  |  |  |  |  |  |  |
| 4 | 24 | [illegible] | 1 | 1 |  |  |  |  |  |  |  |  |  |  | 50 |
| [illegible] | 4 | 2 | 1 | 1 | (6,784 | 1,088 | 360 | 48 | 6,424 | 1,040 | 0 | 53 |  |  | 30 |
| [illegible] | 20 | 3 | 1 | 2 | ( |  |  |  |  |  |  |  |  |  | 90 |
| 6 | [illegible] | 3 | 1 | 2 |  |  |  |  |  |  |  | (5[illegible] |  |  | 15 |
| 6 | [illegible] | 4 | 1 | 3 |  |  |  |  |  |  |  | ( |  |  | 120 |
| 7 | 2 | 1 | 1 | 0 |  |  |  |  |  |  | 0 |  |  |  |  |
| 7 | 6 | 3 | 1 | 2 |  |  |  |  |  |  |  |  |  |  | 60 |
| 7 | 16 | 4 | 1 | 3 |  |  |  |  |  |  |  |  |  |  | 120 |
| 8 | 11 | 3 | 1 | 2 |  |  |  |  |  |  |  |  |  |  | 60 |
| 8 | 13 | 4 | 1 | 3 |  |  |  |  |  |  |  |  |  |  | 120 |
| 9 | 19 | 4 | 1 | 3 |  |  |  |  |  |  |  |  |  |  | 150 |
| 9 | [illegible] | 3 | 1 | 2 |  |  |  |  |  |  |  |  |  |  | 60 |
| 10 | [illegible] | 4 | 1 | 3 |  |  |  |  |  |  |  |  |  |  | 30 |
| 10 | 12.5 | 3 | 1 | 2 |  |  |  |  |  |  |  |  |  |  | 120 |
| 10 | 6 | 2 | 1 | 1 |  |  |  |  |  |  |  |  |  |  | 60 |
| 11 | 24 | 2 | 1 | 1 |  |  |  |  |  |  |  |  |  |  | 90 |
| 12 | 8 | 3 | 1 | 2 |  |  |  |  |  |  | 0 |  |  |  | 30 |
| 12 | 16 | 4 | 1 | 3 |  |  |  |  |  |  |  |  |  |  | 120 |
| 13 | 24 | 4 | 1 | 3 |  |  |  |  |  |  | 1 |  |  |  | 150 |
| 14 | 24 | 4 | 1 | 3 |  |  |  |  |  |  | Trace |  |  |  | 120 |
| 15 | 24 | 4 | 1 | 3 |  |  |  |  |  |  | 1 |  |  |  | 180 |
| 16 | 8 | 4 | 1 | 3 |  |  |  |  |  |  | (0.5 | 172 |  |  | 30 |
| 16 | 16 | [illegible] | 1 | 4 |  |  |  |  |  |  | ( |  |  |  | 120 |
| 17 | 16 | [illegible] | 1 | 2 |  |  |  |  |  |  | (1.0 |  |  |  | 15 |
| 17 | 8 | 2 | 1 | 1 |  |  |  |  |  |  | ( |  |  |  |  |
| 18 | 20 | 2 | 1 | 1 | (864 | 160 | 76 | 40 | 788 | 120 | Trace | 23 | 8,912 | 4,848 |  |
| 18 | 4 | 4 | 1 | 3 | ( |  |  |  |  |  |  |  |  |  |  |
| 19 | 24 | [illegible] | 1 | 4 | 3,112 | 308 |  |  |  |  | Trace | 102 |  |  |  |
| [illegible] | 8 | 4 | 1 | 3 |  |  |  |  |  |  | (Trace |  | (16,740 | 11,360 | 60 |
| [illegible] | 16 | [illegible] | 1 | 4 |  |  |  |  |  |  | ( |  | ( |  |  |
| 21 | 24 | 3 | 1 | 3 | 2,176 | 260 |  |  |  |  |  | 167 |  |  | 60 |
| 22 | 24 | [illegible] | 1 | 2 |  |  |  |  |  |  | Trace |  |  |  |  |
| 23 | 15 | 4 | 1 | 3 |  |  |  |  |  |  |  |  |  |  |  |
| 23 | 8 | 3 | 1 | 2 |  |  |  |  |  |  |  |  |  |  |  |
| 24 | 24 | 2 | 1 | 1 |  |  |  |  |  |  | Trace |  |  |  |  |
| 25 | 24 | 2 | 1 | 1 |  |  |  |  |  |  | Trace |  |  |  |  |
| 26 | 15 | [illegible] | 1 | 4 |  |  |  |  |  |  | 1 |  |  |  |  |
| 26 | [illegible] |  | 1 | 1 |  |  |  |  |  |  |  |  |  |  | 90 |
| 27 | 24 |  | 1 | 4 | 3,283 | 256 | 304 | 208 | 2,976 | 48 |  |  |  |  | 60 |
| 28 | 24 |  | 1 | 4 | 3,368 | 384 | 520 | 276 | 2,848 | 108 |  |  | 12,672 | [illegible] | 90 |
| [illegible] | 14 |  | 1 | 4 | (3,104 | 440 | 460 | 196 | 2,644 | 244 |  |  |  |  |  |
| [illegible] | [illegible] |  | [illegible] | [illegible] |  |  |  |  |  |  |  |  |  |  |  |

TABLE A-21   SECONDARY SETTLING BASIN OPERATION AND ANALYSES
OF COMPOSITE SAMPLES

MARCH, 1968

| | | FLOWS, gpm | | | EFFLUENT | | | | | | | | | | | RETURN SLUDGE | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | SOLIDS, mg/l | | | | | | | | | | | | | |
| | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | | | |
| Day of Month | Hours Operated | Influent | Return Sludge | Effluent | Total | Vol | Total | Vol. | Total | Vol. | Settleable Solids, ml/l | BOD mg/l | Calcium mg/l CaCO$_3$ | Sulfide$^{(1)}$ mg/l | Chromium mg/l | Total Solids, mg/l | Total Vol Solids, mg/l | Sludge Wasted, gals |
| 1 | 15 | 5 | 1 | 4 | | | | | | | | | | | | 47,540 | 29,564 | |
| | 9 | 3 | 1 | 2 | | | | | | | | | | | | | | |
| 2 | 18 | 3 | 1 | 2 | | | | | | | | | | | | | | |
| | 6 | 2 | 1 | 1 | | | | | | | 0.5 | | | | | | | |
| 3 | 24 | 2 | 1 | 1 | 1,104 | 152 | 188 | 20 | 916 | 132 | Trace | 19 | | | | | | |
| 4 | 12 | 2 | 1 | 1 | | | | | | | | | | | | | | |
| | 12 | 5 | 1 | 4 | 1,120 | 156 | 120 | 52 | 100 | 104 | | 36 | | | | | | 30 |
| 5 | 24 | 5 | 1 | 4 | | | | | | | 5 | | | | | 13,664 | 9,236 | 60 |
| 6 | 24 | 5 | 1 | 4 | | | | | | | 9 | | | | | | | |
| 7 | 24 | 5 | 1 | 4 | | | | | | | 5 | | | | | | | |
| 8 | 24 | 5 | 1 | 4 | 1,884 | 308 | 408 | 232 | 1,476 | 76 | 2.5 | | | | | 12,972 | 9,460 | 90 |
| 9 | 18 | 3 | 1 | 2 | | | | | | | | | | | | | | |
| | 6 | 2 | 1 | 1 | | | | | | | Trace | | | | | | | 30 |
| 10 | 19 | 2 | 1 | 2 | | | | | | | | | | | | | | |
| | 5 | 9 | 1 | 3 | 684 | 240 | 212 | 104 | 472 | 136 | 2.1 | | | | | | | 90 |
| 11 | 10 | 4 | 1 | 3 | 1,368 | 440 | 392 | 396 | 976 | 44 | 7 | 100 | | | | 10,036 | 7,480 | |
| | 14 | 5 | 1 | 4 | | | | | | | | | | | | | | |
| 12 | 24 | 5 | 1 | 4 | 784 | 548 | 284 | 148 | 500 | 400 | 10 | 387 | | | | | | |
| 13 | 24 | 5 | 1 | 4 | 1,840 | 644 | 1,556 | 316 | 284 | 328 | 8 | 288 | | | | 13,332 | 7,708 | |
| 14 | 24 | 6 | 2 | 4 | 1,992 | 412 | 510 | 280 | 1,482 | 132 | 8 | 245 | | | | 3,804 | 1,892 | |
| 15 | 24 | 6 | 2 | 4 | | | | | | | 6.5 | | | | | | | |
| 16 | 18 | 4 | 2 | 2 | | | | | | | Trace | | | | | | | |
| | 6 | 3 | 2 | 1 | | | | | | | | | | | | | | |
| 17 | 19 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | |
| 17 | 3 | 5 | 2 | 3 | | | | | | | | | | | | | | |
| 17 | 2 | 4.5 | 2 | 2.5 | | | | | | | | | | | | | | |
| 18 | 8 | 4 | 2 | 2 | | | | | | | 1.5 | | | | | | | |
| 18 | 8 | 3 | 2 | 1 | | | | | | | | | | | | | | |
| 18 | 8 | 5 | 2 | 3 | | | | | | | | | | | | | | |
| 19 | 24 | 5 | 2 | 3 | | | | | | | 11 | 175 | | | | | | 30 |
| 20 | 24 | 5 | 2 | 3 | | | | | | | 7 | 110 | | | | | | 60 |
| 21 | 24 | 5 | 2 | 3 | | | | | | | 6 | 155 | | | | | | 60 |
| 22 | 18 | 5 | 2 | 3 | 2,524 | 372 | 356 | 252 | 2,168 | 120 | 4.5 | 88 | 222 | | | | | 30 |
| 22 | 6 | 3 | 2 | 1 | | | | | | | | | | | | | | |
| 23 | 24 | 3 | 2 | 1 | | | | | | | 0.5 | | | | | | | 30 |
| 24 | 24 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | |
| 25 | 24 | 5 | 2 | 3 | 952 | 228 | 152 | 136 | 800 | 92 | Trace | 44 | 198 | | | 5,088 | 2,632 | 30 |
| 26 | 24 | 5 | 3 | 3 | 1,362 | 140 | 150 | 104 | 1,212 | 36 | 3.0 | 35 | | | | 4,442 | 1,968 | 30 |
| 27 | 24 | 5 | 2 | 3 | 1,862 | 196 | 158 | 138 | 1,704 | 58 | 1.0 | 100 | 395 | Neg. | | 6,408 | 3,456 | 60 |
| 28 | 24 | 5 | 2 | 3 | 2,320 | 252 | 224 | 164 | 2,096 | 88 | 0.5 | 97 | 410 | 5.7 | | 5,792 | 2,838 | |
| 29 | 24 | 5 | 2 | 3 | 3,236 | 276 | 188 | 190 | 2,048 | 86 | 1.5 | 81 | 518 | 5.95 | 6.4 | 4,002 | 2,122 | |
| 30 | 24 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | 30 |
| 31 | 24 | 3 | 2 | 1 | | | | | | | | | | | | | | |

Note (1) Iodine demand as sulfide.

TABLE A-22. SECONDARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

APRIL, 1968

| | | | | | EFFLUENT | | | | | | | | | | | RETURN SLUDGE | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FLOWS, gpm | | | SOLIDS, mg/l | | | | | | | | | | | | | | |
| | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | | | | |
| Day of Month | Hours Operated | Influent | Return Sludge | Effluent | Total | Vol. | Total | Vol. | Total | Vol. | Settleable Solids, ml/l | BOD mg/l | Calcium mg/l CaCO3 | Sulfide(1) mg/l | Chromium mg/l | Total Solids, mg/l | Total Vol. Solids, mg/l | Chromium mg/l | Sludge Wasted, gals |
| 1 | 24 | 5 | 2 | 3 | 1,342 | 142 | 54 | 64 | 1,288 | 78 | Trace | 59 | 202 | 1.12 | 2.8 | 5,866 | 3,308 | 62 | |
| 2 | 24 | 5 | 2 | 3 | 1,216 | 342 | 342 | 240 | 874 | 102 | 9.0 | 159 | 195 | 8.15 | 5.0 | 8,946 | 2,448 | 81 | 30 |
| 3 | 24 | 5 | 2 | 3 | | | | | | | 0.25 | | | | | | | | |
| 4 | 24 | 5 | 2 | 3 | | | | | | | | | | | | | | | |
| 5 | 24 | 5 | 2 | 3 | | | | | | | | | | | | | | | |
| 6 | 24 | 3 | 2 | 1 | | | | | | | 0 | | | | | | | | |
| 7 | 24 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | | |
| 8 | 24 | 3 | 2 | 1 | | | | | | | | | | | | | | | |
| 9 | 24 | 3 | 2 | 1 | | | | | | | | | | | | | | | |
| 10 | 24 | 3 | 2 | 1 | | | | | | | | | | | | | | | |
| 11 | 24 | 4 | 3 | 1 | | | | | | | | | | | | | | | |
| 12 | 24 | 4 | 3 | 1 | | | | | | | | | | | | | | | |
| 13 | 24 | 4 | 3 | 1 | | | | | | | | | | | | | | | 60 |
| 14 | 24 | 4 | 3 | 1 | | | | | | | | | | | | | | | 30 |
| 15 | 24 | 4 | 3 | 1 | | | | | | | | | | | | | | | 30 |
| 16 | 24 | 4 | 3 | 1 | | | | | | | | | | | | | | | 30 |
| 17 | 24 | 1.5 | 0.5 | 1 | | | | | | | | | | | | | | | 30 |
| 18 | 24 | 2 | 1 | 1 | | | | | | | | | | | | | | | |
| 19 | 24 | 2 | 1 | 1 | | | | | | | | | | | | | | | |
| 20 | 24 | 2 | 1 | 1 | | | | | | | | | | | | | | | |
| 21 | 24 | 2 | 1 | 1 | | | | | | | | | | | | | | | |
| 22 | 24 | 2 | 1 | 1 | | | | | | | | | | | | | | | 30 |
| 23 | 24 | 2 | 1 | 1 | | | | | | | | | | | | | | | |
| 24 | 24 | 3 | 1 | 2 | | | | | | | 0 | 79 | 260 | 4.4 | | | | | 30 |
| 25 | 24 | 4 | 2 | 2 | 1,978 | 344 | 68 | 206 | 1,910 | 138 | 0 | 49 | 270 | Neg. | | | | | |
| 26 | 24 | 4 | 2 | 2 | 1,820 | 148 | 122 | 76 | 1,698 | 72 | 0 | 105 | 250 | Neg. | | 10,484 | 7,166 | | |
| 27 | 24 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | | 30 |
| 28 | 24 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | | |
| 29 | 24 | 4 | 2 | 2 | 1,100 | 130 | 66 | 44 | 1,034 | 86 | 0 | 54 | 168 | Neg. | | | | | 90 |
| 30 | 24 | 5 | 2 | 3 | 1,586 | 102 | 70 | 0 | 1,516 | 116 | 0 | 75 | 260 | Neg. | | 10,564 | 7,866 | | 60 |

Note (1) Iodine demand as sulfide.

## TABLE A-23. SECONDARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

MAY, 1968

| | | EFFLUENT | | | | | | | | | | | | | | RETURN SLUDGE | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FLOWS, gpm | | | SOLIDS, mg/l | | | | | | | | | | | | | | | | |
| | | | | | TOTAL | | SUSPENDED | | DISSOLVED | | | | | | | | | | | | |
| Day of Month | Hours Operated | Influent | Return Sludge | Effluent | Total | Vol. | Total | Vol. | Total | Vol. | Settleable Solids, ml/l | BOD mg/l | Calcium mg/l CaCO$_3$ | Sulfide mg/l | Chromium mg/l | Total Solids, mg/l | Total Vol. Solids, mg/l | Calcium mg/l | Sulfide mg/l | Chromium mg/l | Sludge Wasted, gals |
| 1 | 24 | 5 | 2 | 3 | 2,392 | 148 | 122 | 54 | 2,270 | 94 | | 79 | | | | 17,394 | 11,728 | | | | 60 |
| 2 | 24 | 5 | 2 | 3 | 2,776 | 180 | 50 | 40 | 2,726 | 140 | 0 | 80 | 351 | | | 7,776 | 4,130 | | | | 90 |
| 3 | 24 | 5 | 2 | 3 | 2,804 | 134 | 140 | 76 | 2,664 | 58 | | 61 | 360 | | | 11,316 | 7,808 | | | | 60 |
| 4 | 24 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | 30 |
| 5 | 24 | 3 | 2 | 1 | | | | | | | | | | | | | | | | | 0 |
| 6 | 24 | 5 | 2 | 3 | 1,832 | 192 | 162 | 102 | 1,670 | 90 | | 38 | 291 | 0.4 | 2.2 | 10,872 | 7,296 | 194 | | 231 | 60 |
| 7 | 24 | 5 | 2 | 3 | 3,582 | 184 | 174 | 74 | 3,408 | 110 | 0 | 94 | 469 | | | 17,392 | 12,084 | | | | 90 |
| 8 | 24 | 5 | 2 | 3 | 3,794 | 1,048 | 2,108 | 934 | 1,686 | 114 | | 48 | 408 | 0.9 | 1.9 | 18,816 | 13,328 | 303 | 2.1 | 289 | 90 |
| 9 | 24 | 5 | 2 | 3 | 2,836 | 100 | 1,148 | 34 | 2,688 | 66 | | 28 | 428 | | | 18,080 | 13,248 | | | | 60 |
| 10 | 24 | 5 | 2 | 3 | 2,952 | 206 | 120 | 120 | 2,832 | 86 | 0 | 35 | 436 | 0.8 | | 20,262 | 15,086 | | | | 60 |
| 11 | 24 | 3 | 2 | 1 | | | | | | | 0 | | | | | | | | | | 90 |
| 12 | 24 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | | | | 30 |
| 13 | 24 | 6.5 | 2 | 4.5 | 2,204 | 168 | 260 | 78 | 1,944 | 90 | Trace | 36 | 307 | | | 9,780 | 6,406 | | | | 90 |
| 14 | 24 | 6.5 | 2 | 4.5 | 3,246 | 636 | 666 | 524 | 2,580 | 112 | 0.6 | 545 | 501 | 6.0 | 13.6 | 11,974 | 8,324 | 1,616 | 13 | 170 | 150 |
| 15 | 24 | 6.5 | 2 | 4.5 | | | | | | | | | | | | | | | | | 90 |
| 16 | 24 | 6.5 | 2 | 4.5 | 4,250 | 164 | 38 | 34 | 4,212 | 130 | | 39 | 493 | 0.2 | 0.5 | 17,938 | 10,658 | 2,900 | 125 | 138 | 90 |
| 17 | 24 | 6.5 | 2 | 4.5 | 3,364 | 172 | 180 | 56 | 3,184 | 116 | 8.0 | 42 | 465 | | | 17,568 | 11,196 | | | | 90 |
| 18 | 24 | 3.5 | 2 | 1.5 | | | | | | | 15.0 | | | | | | | | | | 90 |
| 19 | 24 | 3.5 | 2 | 1.5 | | | | | | | Trace | | | | | | | | | | 60 |
| 20 | 24 | 7.7 | 2 | 5.5 | 2,588 | 154 | 88 | 10 | 2,500 | 144 | 0 | 73 | 295 | | | 21,108 | 14,182 | | | | 90 |
| 21 | 24 | 8 | 2 | 6 | 4,304 | 474 | 410 | 164 | 3,894 | 310 | 5.0 | 234 | 445 | 1.4 | 3.0 | 26,836 | 15,438 | 6,850 | 299 | 145 | 60 |
| 22 | 24 | 8 | 2 | 6 | 3,680 | 450 | 202 | 100 | 3,478 | 350 | 7.5 | 186 | 545 | | | 22,848 | 11,794 | | | | 60 |
| 23 | 24 | 8 | 2 | 6 | 5,106 | 442 | 402 | 160 | 4,704 | 282 | 3.2 | 240 | 602 | 4.0 | 2.8 | 24,094 | 11,682 | 6,420 | 69 | 298 | 60 |
| 24 | 24 | 8 | 2 | 6 | 5,240 | 228 | 2,170 | 66 | 3,070 | 162 | 1.7 | 100 | 466 | | | 17,344 | 10,254 | | | | 90 |
| 25 | 12 | 4 | 2 | 2 | | | | | | | Trace | | | | | | | | | | 90 |
| | 12 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | | | | |
| 26 | 24 | 3 | 2 | 1 | | | | | | | Trace | | | | | | | | | | 0 |
| 27 | 24 | 9 | 2 | 7 | 1,912 | 208 | 164 | 78 | 1,748 | 130 | Trace | 73 | 311 | 2.2 | 1.5 | 17,346 | 11,740 | | | 212 | 150 |
| 28 | 24 | 9.5 | 2 | 7.5 | 3,094 | 404 | 358 | 220 | 2,736 | 184 | 6.5 | 120 | 350 | | | 17,324 | 11,766 | | | | 150 |
| 29 | 24 | 9.5 | 2 | 7.5 | 2,934 | 154 | 270 | 122 | 3,204 | 276 | | 99 | 451 | 1.3 | 19.0 | 11,762 | 7,182 | 1,630 | | 176 | 180 |
| 30 | 24 | 2.5 | 2 | 0.5 | | | | | | | Trace | | | | | | | | | | 90 |
| 31 | 24 | 9.5 | 2 | 7.5 | 1,726 | 228 | | | | | | 48 | 295 | | | 7,944 | 5,090 | | | | 60 |

## TABLE A-24. SECONDARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

### JUNE, 1968

|  |  |  |  |  | EFFLUENT |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | FLOWS, gpm |  |  | SOLIDS, mg/l |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  | TOTAL |  | SUSPENDED |  | DISSOLVED |  |  |  |  |  |  |
| Day of Month | Hours Operated | Influent | Return Sludge | Effluent | Total | Vol. | Total | Vol. | Total | Vol. | Settleable Solids, ml l | BOD mg/l | Calcium mg/l $CaCO_3$ | Chloride mg/l | Sludge Wasted, gals |
| 1 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  |  |  |  |  | 30 |
| 2 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  |  |  |  |  | 0 |
| 3 | 24 | 4.5 | 2 | 2.5 |  |  |  |  |  |  | Trace | 28 |  |  | 60 |
| 4 | 24 | 4.5 | 2 | 2.5 | 2,958 | 178 | 246 | 76 | 2,712 | 102 | Trace | 35 | 435 |  | 150 |
| 5 | 24 | 4.5 | 2 | 2.5 | 3,058 | 148 | 186 | 36 | 2,872 | 112 | Trace | 30 | 360 |  | 180 |
| 6 | 24 | 4.5 | 2 | 2.5 | 2,896 | 164 | 190 | 54 | 2,706 | 110 | Trace | 23 | 360 |  | 180 |
| 7 | 24 | 4.5 | 2 | 2.5 | 3,444 | 256 | 354 | 56 | 3,090 | 200 | Trace | 39 | 470 |  | 150 |
| 8 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  | 0 |  |  |  | 150 |
| 9 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  | Trace |  |  |  | 60 |
| 10 | 24 | 4.5 | 2 | 2.5 | 2,092 | 210 | 46 | 54 | 2,046 | 156 | Trace | 24 |  |  | 120 |
| 11 | 24 | 4.5 | 2 | 2.5 | 3,664 | 220 | 182 | 82 | 3,482 | 138 | Trace | 25 | 400 |  | 180 |
| 12 | 24 | 4.5 | 2 | 2.5 | 3,148 | 244 | 96 | 118 | 3,052 | 126 | Trace | 34 | 360 |  | 180 |
| 13 | 24 | 4.5 | 2 | 2.5 | 3,916 | 182 | 108 | 50 | 3,808 | 132 | Trace | 23 | 435 |  | 180 |
| 14 | 24 | 4.5 | 2 | 2.5 |  |  |  |  |  |  | Trace | 14 |  |  | 180 |
| 15 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  | Trace |  |  |  | 150 |
| 16 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  | Trace |  |  |  | 30 |
| 17 | 24 | 4.5 | 2 | 2.5 |  |  | 82 | 66 |  |  | 1.5 | 20 |  |  | 150 |
| 18 | 24 | 4.5 | 2 | 2.5 |  |  | 50 | 40 |  |  | Trace | 15 |  |  | 180 |
| 19 | 24 | 4.5 | 2 | 2.5 |  |  | 62 | 47 |  |  | Trace | 22 |  |  | 180 |
| 20 | 24 | 4.5 | 2 | 2.5 |  |  | 84 | 63 |  |  | Trace | 24 |  |  | 120 |
| 21 | 24 | 4.5 | 2 | 2.5 |  |  | 72 | 56 |  |  | Trace | 24 |  |  | 180 |
| 22 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  | 0 |  |  |  | 120 |
| 23 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  | 0 |  |  |  | 0 |
| 24 | 24 | 4.5 | 2 | 2.5 |  |  | 55 | 49 |  |  | Trace | 93 |  |  | 120 |
| 25 | 24 | 4.5 | 2 | 2.5 |  |  | 30 | 28 |  |  | Trace | 53 |  |  | 150 |
| 26 | 24 | 4.5 | 2 | 2.5 |  |  | 30 | 28 |  |  | Trace | 50 |  |  | 150 |
| 27 | 24 | 4.5 | 2 | 2.5 |  |  | 64 | 57 |  |  | Trace | 10(1) |  | 1,620 | 150 |
| 28 | 24 | 4.5 | 2 | 2.5 |  |  | 62 | 56 |  |  | Trace | 40 |  |  | 150 |
| 29 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  | 0 |  |  |  | 120 |
| 30 | 24 | 2.5 | 2 | 0.5 |  |  |  |  |  |  | Trace |  |  |  | 60 |

Note (1) 3-day BOD.

## TABLE A-25. SECONDARY SETTLING BASIN OPERATION AND ANALYSES OF COMPOSITE SAMPLES

JULY, 1968

| | | FLOWS, gpm | | | EFFLUENT | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Day of Month | Hours Operated | Influent | Return Sludge | Effluent | Suspended Solids, mg/l | Vol. Suspended Solids, mg/l | Settleable Solids, ml/l | BOD mg/l | Chloride mg/l | Sludge Wasted, gals |
| 1 | 24 | 4.5 | 2 | 2.5 | 79 | 72 | 0 | 103 | | 150 |
| 2 | 24 | 4.5 | 2 | 2.5 | 42 | - | 0 | 30 | | 240 |
| 3 | 24 | 4.5 | 2 | 2.5 | | | 0 | 41 | | 180 |
| 4 | 24 | 2.5 | 2 | 0.5 | | | 0 | | | 120 |
| 5 | 24 | 4.5 | 2 | 2.5 | 54 | 50 | 0 | | | 90 |
| 6 | 24 | 2.5 | 2 | 0.5 | | | 0 | | | |
| 7 | 24 | 2.5 | 2 | 0.5 | | | | | | |
| 8 | 24 | 4.5 | 2 | 2.5 | 68 | 60 | 0 | 62 | | 60 |
| 9 | 24 | 4.5 | 2 | 2.5 | 56 | 56 | 0 | 50 | 580 | 120 |
| 10 | 24 | 4.5 | 2 | 2.5 | 128 | 116 | Trace | 54 | 1,000 | 120 |
| 11 | 24 | 4.5 | 2 | 2.5 | 370 | | 0.3 | 50 | | 150 |
| 12 | 12 | 4.5 | 2 | 2.5 | | | | | | 60 |

**1 Accession Number** W 70-00163

**2 Subject Field & Group** 05D

## SELECTED WATER RESOURCES ABSTRACTS
### INPUT TRANSACTION FORM

**5 Organization** A.C. Lawrence Leather Company, South Paris, Maine

**6 Title** ACTIVATED SLUDGE TREATMENT OF CHROME TANNERY WASTES, A Pilot Study of Treating Combined Chrome Tannery Wastes and Domestic Sewage

**10 Author(s)**

**11 Date**

**12 Pages**

**15 Contract Number** Grant No. WPRD 133-01-68

**16 Project Number** FWPCA Program No. 12120

**21 Note**

**22 Citation** Water Pollution Control Series, FWPCA Report ORD-5, September, 1969. 174p, 48 tab, 36 fig, 13 ref, append

**23 Descriptors (Starred First)**

**25 Identifiers (Starred First)**

**27 Abstract**

The A.C. Lawrence Leather Company tannery at South Paris, Maine is a chrome side upper leather tannery. About 220 people are employed at the tannery and about 2,500 hides are processed each day. The water use at the tannery is about 1.0 mgd. Each day the waste discharged from the tannery contains about 8,500 lbs of 5-day, 20°C BOD, 70,000 lbs of total solids, of which about 17,000 lbs are suspended and 53,000 lbs are dissolved. The pH of the wastewater varies from 5.0 to 12.0. The daily waste discharge also contains about 6,000 lbs of calcium, as $CaCO_3$, 500 lbs of sulfides, and 1,800 lbs of chromium.

A waste treatment process was developed and tested, on pilot plant scale, for the treatment of the tannery wastes in combination with municipal sewage. The process consisted of the following steps in the order specified; equalizing and mixing of the alkaline and acid wastes; primary sedimentation; carbonation followed by upflow sedimentation; addition of degritted municipal sewage; activated sludge treatment and secondary sedimentation of the mixed wastes; and chlorination. The sludges resulting from the treatment of the wastes and sewage were dewatered by centrifuge and were found to be suitable for burial. Design factors for the various steps of the process were developed and are presented in the attached report. Studies were made of the fundamental systems and reactions which form the bases for the processes employed in the pilot plant.

The results of the pilot plant investigation indicate that by use of the methods recommended, mixtures of chrome tannery wastes and municipal sewage can be treated successfully. It may be anticipated that by the employment of the methods recommended, that mixtures of tannery wastes and municipal sewage can be treated to remove more than 90 percent of the BOD and suspended solids together with about 65 percent of the total solids.